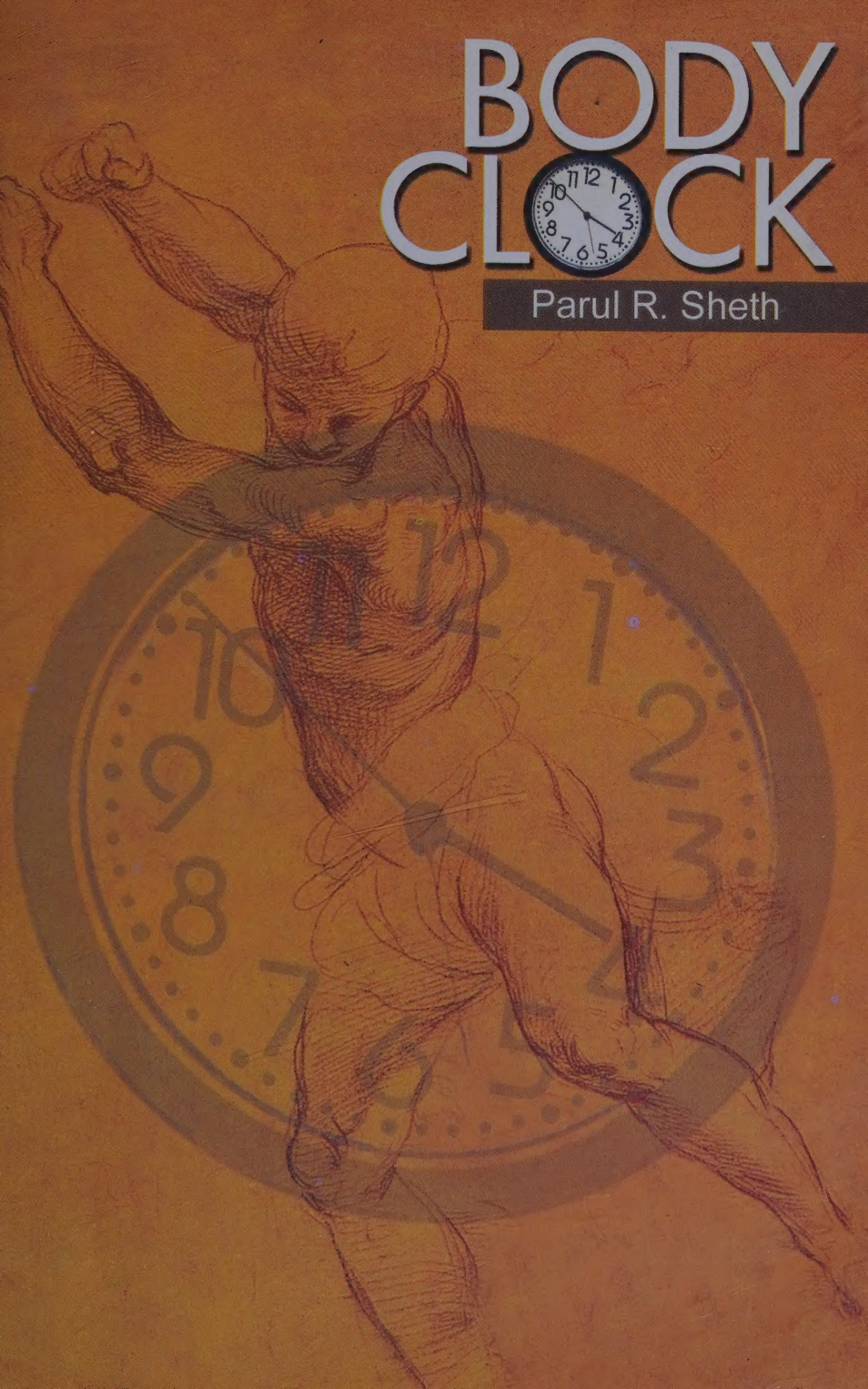
BODY CLOCK

Parul R. Sheth



BODY CLOCK

Popular Science

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PARUL R. SHETH

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To my husband and my son
for their uninterrupted support,
never-ending enthusiasm and encouragement.

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I am indebted to Dr Avinash Bhisey, former Director of Tata Cancer Research Centre, Mumbai, for so readily sparing his valuable time and blessing this work with an apt foreword.

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The acknowledgement cannot be complete without thanking each one of my family members who stood by me and without whose co-operation, it would have been impossible to go through the rigours of writing this book.

Foreword

The coming of dawn brings in a new day and the end of the night. For most, it is just another day that is a part of the universal cycle of day and night, not affecting our day-to-day life. Do these natural cycles of day and night and also of different seasons comprise merely phenomena that we adjust to, as we put on warm clothes during winter with short days or a raincoat in rains? Do the cycles of the Sun, Moon and seasons affect us superficially or do they have a deeper impact on all living beings? Just as there are cycles of day and night, high and low tides, and seasons alternating with one another, all living beings have body rhythms or cycles. They occur in the smallest of animals, in plants, and also in micro-organisms made up of single cells. These are the biological cycles controlled by the body clocks. Our body clock drives different processes in the body as per its schedule. The Sun is the master 'time-keeper' on whom the clocks of all living beings depend for counting time. However, we are neither fully aware of our body clocks nor do we know how and where they function.

Dr Sheth has very lucidly introduced the concept of biological rhythms and body clock in her book *The Body Clock*. She describes, in simple words, the rhythms that occur regularly in complex as well as simpler life forms and shows how they are related to the day and night cycle. Such a diurnal cycle regulates several physiological events in a clockwork precision, based on day and night. Dr Sheth has traced man's efforts to understand the clocks from ancient

times to our present state of understanding. While it is far more difficult to find out where the clock resides in the body in lower organisms, scientists have shown their location in the brain in humans, mammals, reptiles and birds. The book describes regulation of the clock by light and its ability to adjust under different experimental conditions. This is directly related to our understanding of the body's response to stress in time-zone travellers—people who work in day and night shifts and many others.

Dr Sheth has stressed the importance of a normal cycle of wakefulness and sleep, describing the intricacies of sleep and its importance in maintaining good health and an alert mind. Such studies have now initiated a new branch of science—'chronobiology', that has led to rethinking in our approaches for treating man-made problems and known disorders. We thus know that symptoms of some of the diseases are at their peak at certain times of the day/night and can be best diagnosed and also treated at these times. Even drugs may act better at particular times than others.

Can all this scientific knowledge help a common man reorganise his daily life or is it only for the clinicians who treat day-to-day medical problems? Dr Sheth has taken several situations from our daily grind and suggested simple ways to use this information for us to correct the alterations of our body clocks for a healthier life. I am sure the reader will find the book as fascinating, informative and instructive as I did.

Tata Cancer Research Centre
Mumbai

Dr AVINASH BHISEY
Ex-Director

Preface

Body clock and rhythms played on my mind since the time I worked for my Ph.D. at the Institute for Research in Reproduction (ICMR), Mumbai. My colleague and friend Dr P.G. Jayatilak, who worked for his Ph.D. thesis on this subject at the same institute, involved me in a few of his research projects revolving around body rhythms. I toyed with the idea of writing on this topic since that time but, luckily for me, the dream materialised after several years when I got this approval from NBT for writing a book on body clocks. Indeed, it was a dream come true for me.

Ancient cultures too recognised body time. Monuments built by ancient civilisations reflect knowledge of body time as well as planetary time. Demonstrations of the persistence of rhythms and cycles associated with light and darkness in human beings as well as in several other species suggested the existence of biological clocks. Today, the existence of biological clocks is widely accepted by the scientific community and these clocks have also been identified in several species.

Most of us do not know how to tell time—the body time. The brain's clock governs all the possible rhythms in our body. We carry this clock around within us. And yet many of us cannot hear this clock tick.

Today body rhythms are 'hot' again. There has been a major leap in scientific understanding of the body clock. Chronomedicine—treating illnesses keeping the body

clock in mind—is a brand new concept, a new way to maintain and optimise health, and to prevent and treat illnesses. It holds implications for vastly improving the lives of all of us.

1

UNDERSTANDING RHYTHMS

Our body is like a clock: if one wheel be amiss, all the rest are disordered, the whole fabric suffers; with such admirable art and harmony is a man composed.

—Robert Burton, English writer, 17th century

Is there a right time to take your medicine or to conceive a child? Why do some people gain weight during the winter months? Are you more productive at work in the daytime, or in the afternoon? Have you wondered how the salmon knows that it is time to spawn, what tells squirrels and hamsters to get ready to hibernate or why so many teenagers fall asleep at their desks in schools? They say 'timing is everything' (Fig.1.1) and that 'time and tide wait for none'. For a psychologist, timing is a part of the mental awareness of the passage of time. For a biologist on the other hand, timing is activity, movement, development, speed

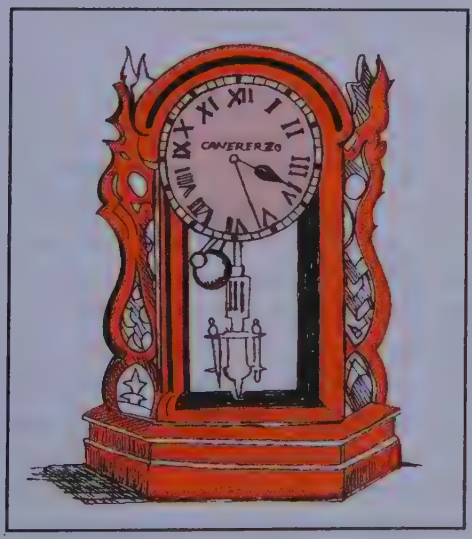

Fig. 1.1: Grandfather's clock.

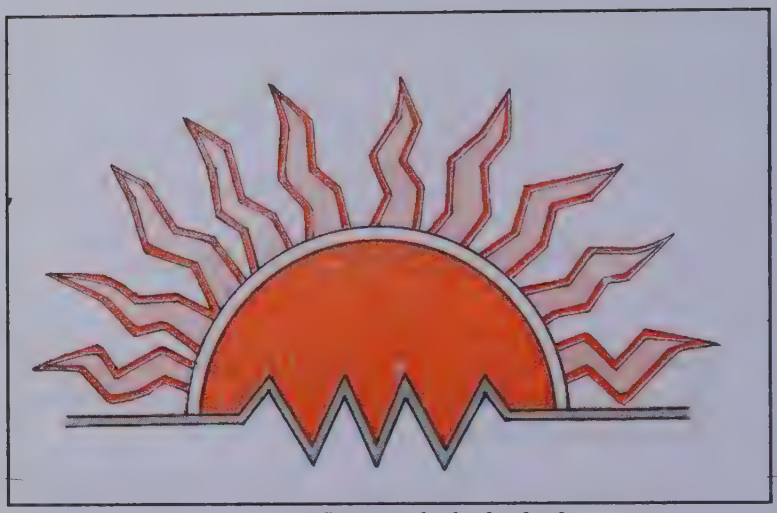

Fig. 1.2: Sun influences the body rhythms.

and growth. A scientist can so easily predict that a red blood cell born in the bone marrow in the month of May will die sometime later in August because he knows that red blood cells on an average live only for 120 days. Yet, there is one common philosophy—that timing is indeed everything for every mental and biological event that occurs in every living being.

Planet Earth is a sentient life form. It too has its own cycles that follow specific patterns, like any other living organism. There is a rhythm in the Earth's movement. It revolves around the Sun in a peculiar way and produces seasons, day and night (Fig. 1.2). The days get longer, and then gradually turn shorter. It seems natural that our ancestors marked their existence by the Sun and made one day the unit of time, dividing it into 24 hours of 60 minutes each. Traditionally, we have also been closely linked to the circumlunar pattern. For instance, for us the waxing and waning of the moon (Fig. 1.3) are linked with the Hindu calender of *tithis – Chouth, Purnima, Amavasya*, etc. They are the salient features for agriculture, religious rites and rituals. The lunar rhythms are conceptualised as being homologous

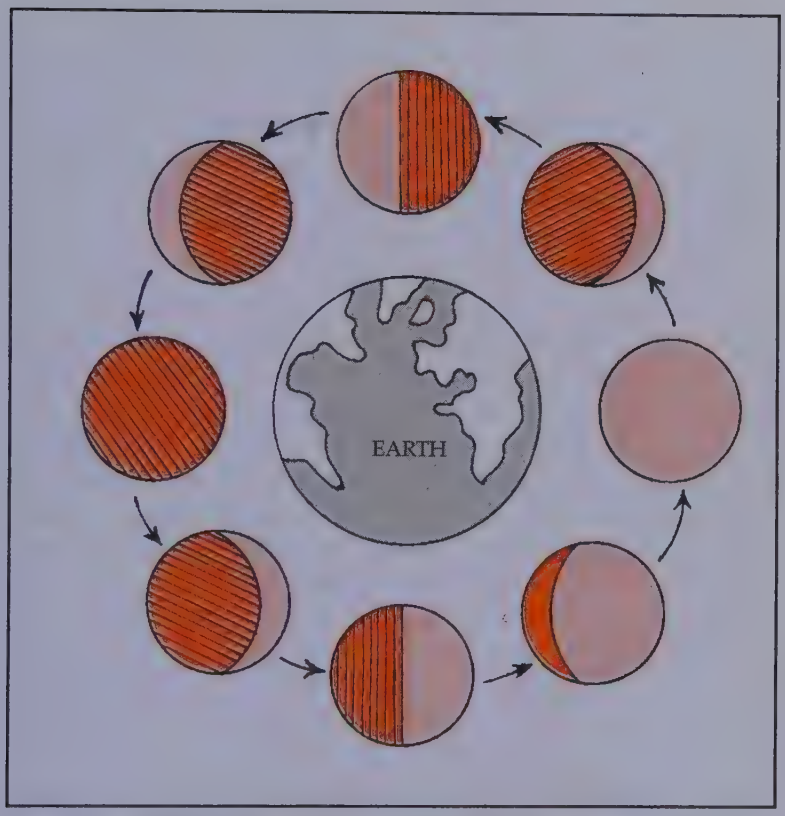

Fig. 1.3: Waxing and waning of the moon.

with cosmic rhythms and the latter are built into the culture of food as well. Even today, in many Indian homes, fasting and feasting are related to the phases of the moon. Thus, the skies become the shared almanac of the people of the world, with the Sun and the Moon serving as visible time-markers. It is in this perceived, or perhaps only subtly sensed, relationship to the cosmos, that clock time and calendar time assume significance.

Monuments built by ancient civilisations are a living proof of this phenomenon. They reflect knowledge of body-time as well as planetary-time. These natural changes tend to influence our lives by showering their effects on many of

our body functions. Shadows cast by the sun on the towering slabs at Stonehenge constructed in south-western England, some 4,000 years ago, show changes in day length over the year. One circle at Stonehenge even holds the correct number of markings to calculate the length of a woman's menstrual cycle or the likelihood of pregnancy; the normal biorhythm that we have accepted as a part of life.

What are biological rhythms? In essence, they are the rhythms of life (Fig. 1.4). All forms of life on Earth, including our bodies, respond rhythmically to the regular cycles of the Sun, Moon, and seasons. We have biorhythms that include hormonal cycles, cellular cycles, sleep-wake cycles and so on. Because of these cycles, our bodies, and to some extent even our mental states, get influenced. Hormonal cycles are controlled by literally many ductless glands located throughout our body. This collection of ductless

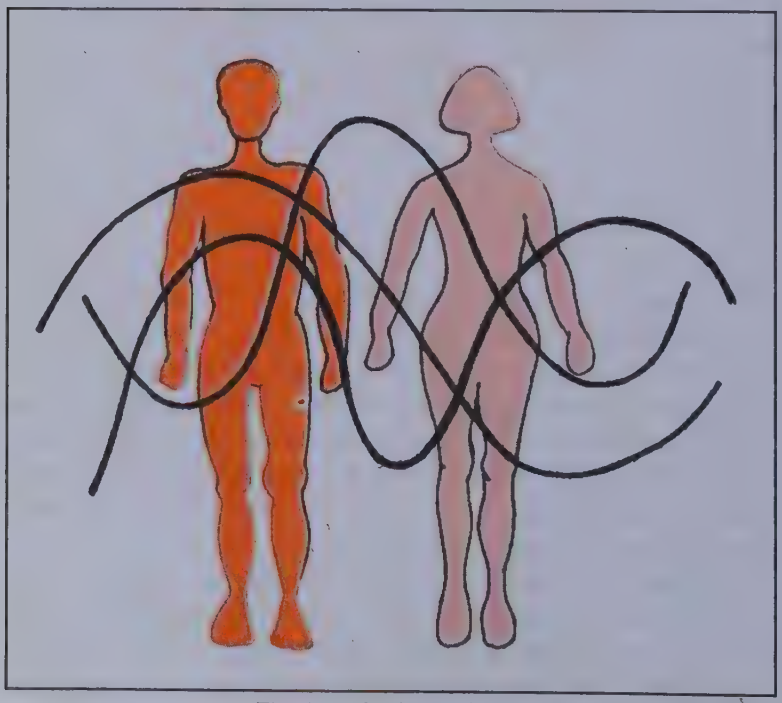

Fig. 1.4: Rhythms of life.

glands is co-ordinated by so-called 'master glands', such as the pituitary, the pineal and the thyroid gland. Over the years, researchers have found that these 'master glands' also seem to have a unique cycle that begins at birth and continues throughout our lives. Each cycle seems to be of a specific duration, with peaks and valleys. The basic three cycles that matter to us are that of the intellect, the emotion, and physical cycles. These flow continuously through the ups and downs we know as 'life'. If you do poorly in a test or presentation, it is likely that your intellect is down. If you had a fight with your spouse or lover, it is likely that your emotions were down and presumably, if you have been under weather, you also feel physically low. When we are born, our cycle begins. Usually once in our life-time the cycle will come full circle and match its start. To many it is a rebirth or change of life between the ages of 18, 35, 65.

Not only do human beings get affected due to these rhythmic changes, but also do plants and animals. There are many things which we do not understand and we do not have much logical explanation regarding them. So many questions arise in our minds. Why is it that birds breed in spring while deer mate in fall? Why is it that Siberian cranes migrate every year at the same time and fly all the way from Russia to India? How do they know that now it is time to migrate? But it was more than 60 years ago that biologist W.R. Brown demonstrated the migratory behaviour of birds in the spring season.

We pay more attention to the watches we wear on our wrists than to clocks we acquire in the womb. The younger ones of animals and humans spend time in the womb. A human being spends nine months in a mother's womb. Likewise, all animals have specific gestation times, which vary from animal to animal. Lemurs, cousins to the earliest of primate ancestors, have a period of gestation lasting just four months. Macaques and squirrel monkeys spend no more than six months within the womb. Gibbons from the ape family are born only after seven months of pre-natal

life. The chimpanzee, one of our closest primate relatives, has a period of gestation just a few weeks shorter than ours. Among the primates, we humans spend the longest period of time within the womb. Why is our gestation period the longest as compared to all these animals? Evolution has endowed us with large brains and given us a complex nervous system. Perhaps, humans possess big brains and bigger brains call for a longer period of gestation. The peculiar and unique aspect about these differences is that each of these events follows a specific time development agenda and a specific rhythm.

A Walk through Time

If you travel to Egypt you will see 24 baboons, which were carved onto the face of a cliff at Abu Simbel, some 3,200 years ago to guard the entrance to a temple of Pharaoh Ramses II. The baboons represent the 24 hours of the day—a way of dividing up time the ancient Egyptians devised some 400 years earlier. The baboons symbolise the Pharaoh's round-the-clock rule. But these baboons in modern-day life are said to influence our body rhythms. Although our body relies on its own rhythms, its own internal clock keeps in check with the baboons—the 24-hour light/dark solar day. Actually, the cycles merely approximate a solar day.

It was in 1959 that Franz Halberg, a German researcher from University of Minnesota, USA, noticed this fact and coined the term circadian, which in Latin is *circa* – 'about' and *dies* – 'a day'. The peaks and troughs in the body are controlled internally, but they are reset to the 24-hour day and the light to which the body is exposed. In ancient times, abbreviation 'circa' referred to the circadian rhythm originating in the Circacus mountains and indicated origin of the knowledge as from an oral history kept with hypnosis. The word 'circus' described a troupe of travelling actors and talented people with animals that follow the sun cycles through a land bringing entertainment, beauty and a degree of mystery. Today, understanding these daily or circadian

rhythms of our bodies is critical for anyone trying to live a successful, happy and healthy life in the modern 24-hour society.

Circadian rhythms occur due to the presence of a biological clock within all living beings. The biological clock is a mysterious timing system that operates in both plants and animals. This system keeps accurate time of days, weeks, months and even years. It also times the activities of living things to keep them in harmony with the regular change in their surroundings. Birds migrate, fish spawn and flowers bloom on schedules set by their inbuilt clocks. Similarly, the biological clock in human beings times our periods of sleep and wakefulness and many other body activities.

But why do living things need biological clocks? This is because such clocks regulate the sequence of tissue and organ formation during the development of many kinds of life. For instance, a plant that produced flowers before it grew roots would die or a newly born baby with teeth but no stomach would starve. Also, biological clocks synchronise the natural rhythms, the times of activity and rest of both the diurnal (daytime) and nocturnal (night-time) animals to ensure that peak activity occurs when food or prey is available. Whether the biological clock within an organism is a single master rhythm or a myriad of associated rhythms is yet controversial.

Biological clocks keep track of rhythmic changes in the environment, including day and night movements of the ocean tides, phases of the moon and seasons of the year. Mostly all living things seem to have internal cycles, called 'biological rhythms' that respond to these external rhythmic changes. The biological rhythms of each particular species seem to be timed to enable the organism to take advantage of the changes in its environment.

The science that deals with the study of biological clocks is called 'chronobiology'. Scientists believe that every living being has its own in-built timing system that operates independently. Others believe that the clocks are

set by the natural rhythms of the Earth's electromagnetic or gravitational forces. Still others suggest that forces, both inside and outside the body, are necessary to keep the clocks accurate. Researchers hope that experiments with plants and animals in outer space, far from the Earth's natural rhythms, may provide more information about how biological clocks work.

Body clocks do change dramatically from early in life to late in life. The human body was designed to sleep at night and be alert and active during the day. Even when babies are only two days old, they know the difference between day and night; they predictably sleep longer at night. A dramatic change in the body clock occurs during the teenage years. Teenagers are programmed to go to sleep late, and to sleep until late hours in the morning. As people grow older, they go to bed earlier, and wake up much earlier than babies, youngsters and adults. Some seniors have problems as they go to bed much too early in the evening to enjoy a normal social life, and then they wake up at three or four in the morning, while the rest of their household is fast asleep.

The biological clock seems to tick off the night-time

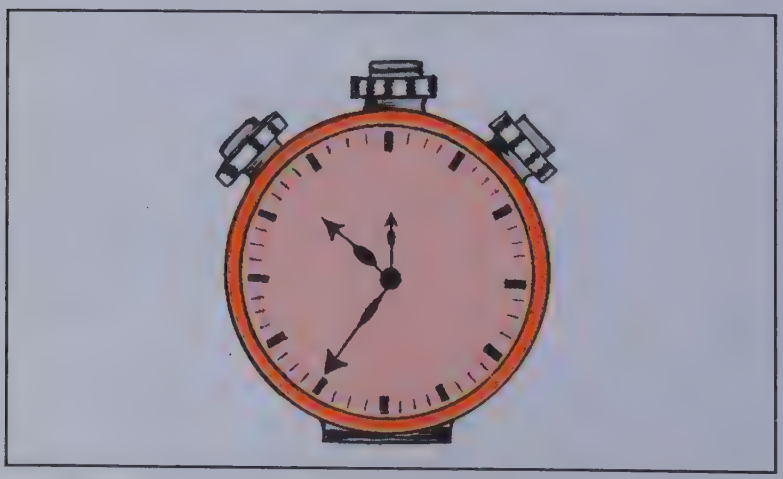

Fig. 1.5: A stopwatch.

hours and 'ring' an alarm in the brain to start the waking process in an indivi-dual. People who have to get up at a certain time in the morning often awa-ken just before the alarm goes off. It is a stopwatch that governs our daily routine (Fig. 1.5). Many of us do not pay much attention to regular bed times and regular wake-up times. As a result, our body rhythms often get markedly disrupted. People who work in the evenings or at night often have trouble sleeping in the daytime because we humans are programmed for daytime activity and night-time sleep. It is difficult for any one of us to sleep as and when we want.

You can best cope with the demands of the body clock by trying to stick to a regular wake-up time seven days a week, regardless of when you go to sleep. This is the most important thing you can do to keep body rhythms in line. Yet, many people in today's non-stop world are required to work at all hours of day and night, or fly across time zones, disrupting their natural patterns of sleeping and waking. By knowing about your own circadian rhythms and respecting your body clock you can learn how to avoid fatigue, keep in good physical shape and obtain the sleep and nutrition you need to stay safe, happy, and healthy. This knowledge is especially important when your job requires you to work for long, demanding or irregular shift-work or night hours.

If circadian rhythms are the basis of biological clocks, they certainly have distinct advantages as time-pieces. Through their entrainment feature, circadian clocks would adjust daily to the natural 24-hour cycle of Earth's rotation, regardless of the rhythm's natural frequency. Through their phase-shift feature, the clocks in travellers who jet across many time zones would adjust within days to new light-dark cycles.

Concept of Time

St. Augustine, a Christian saint, contributed to knowledge of how time is involved in central issues of religion,

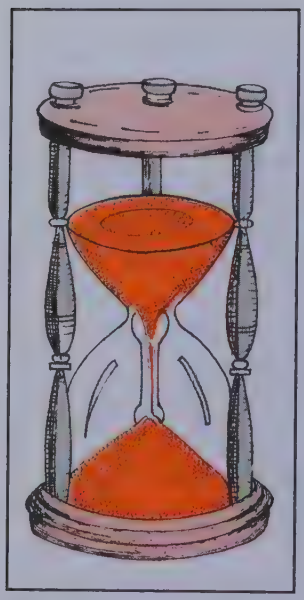

Fig. 1.6: An hour glass.

philosophy and psychology without even mentioning the hour glass or the sundial (Figs. 1.6, 1.7)—the earlier instruments of natural science. After many centuries the human time got divorced from its religious meaning and is now studied in relation to physical periodicities measured by clocks. Albert Einstein once wrote: 'The separation between past, present and future has only the meaning of an illusion, although a tenacious one.'

According to some researchers, the biological rhythms

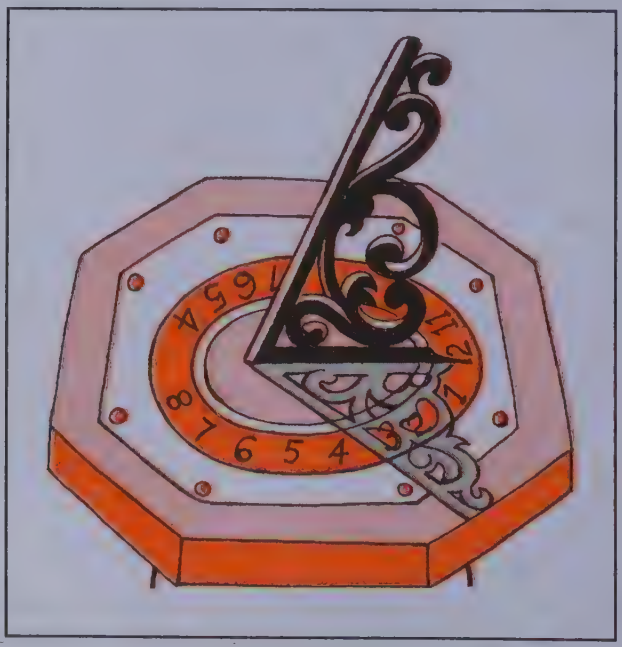

Fig. 1.7: Sundial.

are endogenous—regulated by internal biological clock while others are of the opinion that they are exogenous—controlled by environmental stimuli. However, recent studies show that the biological clock often interacts to some extent, with both external and internal stimuli. Surprisingly, body rhythms in relation to a solar day and night are not exclusive to humans alone. Circadian rhythms or 24-hour rhythms are found in just about every creature on this planet—from bacteria to bread moulds to birds, bees and bears. Each organism is capable of incorporating the internal programme of movements of the Sun into its cells. Thus, it prepares itself in advance to the oncoming changes in the environment. This internal calendar is very critical to life. A very good example is that of a fruit fly (Fig.1.8). Fruit flies

Fig. 1.8: The fruit fly.

emerge from their immature pupae stage into their adult flying stage about two hours before noon. But the movements of the Sun do not trigger the escape *per se*. The flies emerge before noon because the instructions are buried into their genes.

Try and raise 14 generations of fruit flies under continuous dim light, which in turn remove the natural light

and dark rhythm, and the 15th generation of flies will still emerge from the pupae stage on perfect schedule—about two hours before noon!

2

RHYTHMS IN PLANTS AND ANIMALS

Night's darkness is a bag that bursts with the gold of the dawn.

—Rabindranath Tagore, poet

There is an obvious rhythmicity to the Earth. The tilt of its axis and, along with it, its annual revolution around the Sun, produces seasons. The Moon waxes and wanes over a 30-day period. High and low tides occur almost every 24 hours in the sea. Plants and animals have adapted to these cyclic changes in their environment (Fig. 2.1, 2.2). They regulate their own activities accordingly and try and get maximum benefit out of it. Humans, monkeys, cattle, sparrow, pigeon, butterfly, all rest during the night-time and seek food during the day. Therefore they are called 'diurnal'. There are other animals such as bat, owl,

Fig. 2.1: Birds, reptiles, flies have adapted to rhythmic changes in the environment.

Fig. 2.2: Owl, rat, cockroach, all adapt themselves to rhythmic changes.

moth, etc. that hunt during the night and sleep during the day; they are termed as 'nocturnal'. Many birds and animals, such as gaur, are active in mornings and evenings and turn inactive at mid-day and night. These are termed as 'crepuscular'. Such rhythmic activities in organisms are called 'biological rhythms'. The rhythmic activity of most living beings at certain times of the day and night offers strong support for the existence of biological clocks.

Plant and animal behaviours are not merely dependent on the length of day or night as such. Scientists say that animals may measure time internally, starting at the beginning of either the break of day or the beginning of night. Perhaps it is the circadian rhythm of sensitivity to light that acts as the inducing or inhibiting factor. It is true that for most birds, the height of breeding season is spring; for deer the mating season is autumn. Brook trout spawn in

autumn while bass do so in the late spring or summer. Following breeding season, the gonads of many birds regress spontaneously to an immature state. However, a brief period of extra time may be needed to trigger a sensitive stage that responds specifically to light. The breeding period of ferret, for example, can be started prematurely by exposing the animal to 12 hours of artificial light each day for a month, in addition to normal sunlight during the day. If you see a rain-tree, the tree raises its leaves during the daytime and lowers them at night. These are sleep movements, which take place even when the plant is kept under artificial conditions of constant light and temperature.

Rhythms—Age-old Phenomenon

Research in the area of biological clocks did not begin with humans. Early research was done on a variety of animals including rats, hamsters, sparrows, lizards, marine snails, and fruit flies. The choice of an animal depended on many considerations such as size, rate of reproduction, expense to maintain, availability and also behavioural issues, such as whether it entrained easily and what environmental factors seemed to affect its behaviour.

In plants, the 24-hour day/night cycle controls processes such as leaf and petal movements, the opening and closing of stomata pores, the discharge of floral fragrances (Fig.2.3, 2.4) and many metabolic activities, especially those associated with photosynthesis. The circadian clock

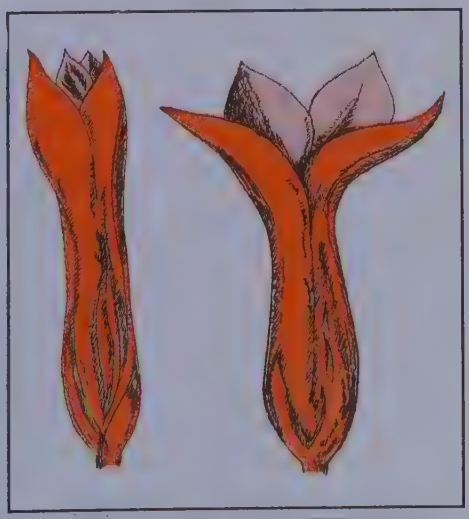

Fig. 2.3: Petal movements in flowers.

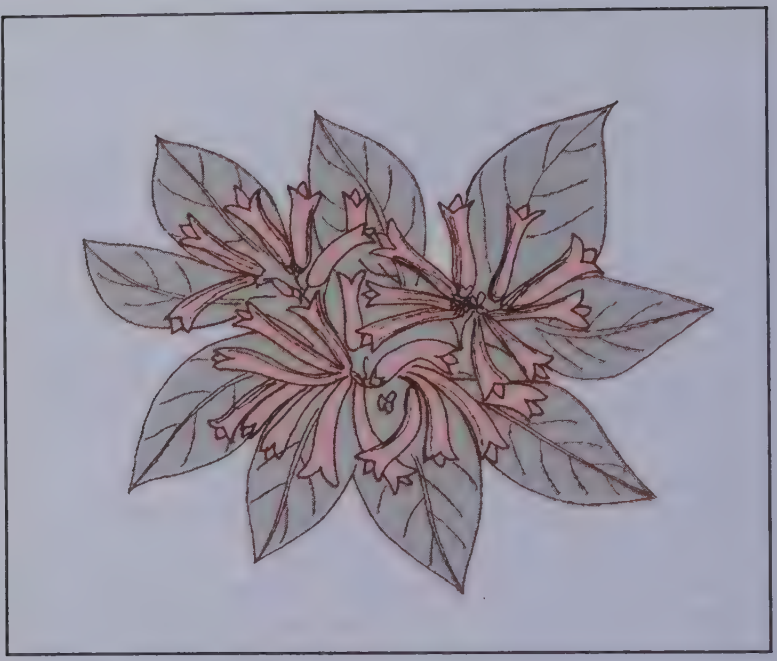

Fig. 2.4: Discharge of floral fragrance.

also influences seasonal cycles that depend on day-length, including the regulation of flowering. This photoperiodic system appears to depend on the circadian clock to measure the duration of the day or night, thus monitoring the passage of the seasons.

Circadian or daily rhythms in plants and animals have been noticed since early times. As early as 4th century B.C., Androsthenes (Fig. 2.5), the scribe of Alexander the Great, noted that the leaves of certain trees opened during the day and closed at night. In 1729, French astronomer Jean Jacques d'Ortous de Mairan, who had immense interest in biology, conducted the first known experiment on biological rhythms. He noticed that his heliotrope plant's leaves opened during the day and folded at night. When he kept the plant in total darkness, the rhythm continued; however, the plant was not disrupted by the absence of daylight as

an environmental cue. But one thing was certain—that the slow dance of the heliotrope's leaves coincided with the plant's internal rhythm and required no movement of the Sun to initiate it.

Charles Darwin (Fig.2.6), the most famous scientist known for his ideas on evolution through natural selection, in his later years became fascinated with plant movements while trying to find an evolutionary relationship among them. He carried out hundreds of experiments to keep track of the movements of the different varieties of plant leaves. From his experiments, Darwin concluded that plants were moving their leaves so as to expose the smallest possible leaf surface to the night temperatures. His book, *The Power of Movements*

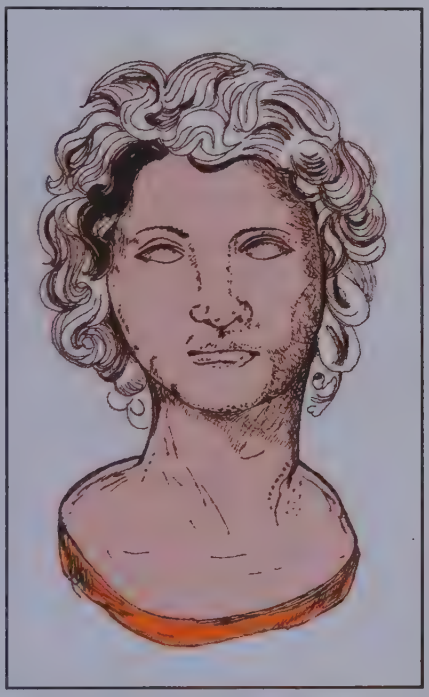

Fig. 2.5: Androthenes (4th century B.C.).

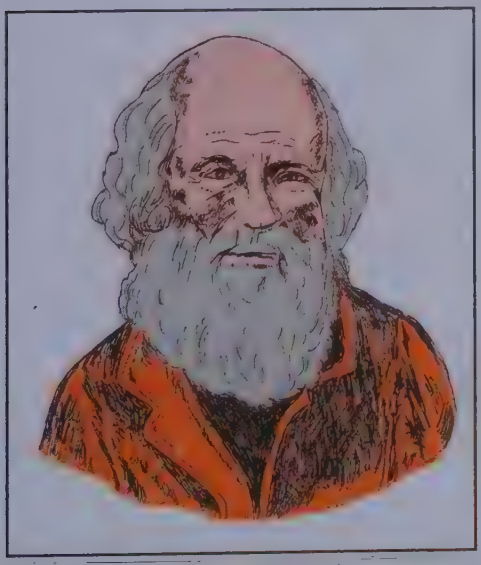

Fig. 2.6: Charles Darwin.

in Plants details his work. In the following years, scientists debated whether the rhythms arose from forces external to the plant or were endogenous.

Circadian rhythms were known to naturalists centuries ago. The great 18th-century Swedish botanist, Carolus Linnaeus, grew a garden that told time. Two centuries before modern gardeners noticed that their day lilies closed at night, Linnaeus discovered that the petals of many flower species opened and closed at regular times. He created a garden with flowers, which opened at various times so that he could tell the time of day by looking at his garden (Fig. 2.7). Nothing exciting happened for many years, until the early 1900's, when Karl von Frisch observed that bees visited flowers (Fig. 2.8) only at specific times. He and Ingeborg

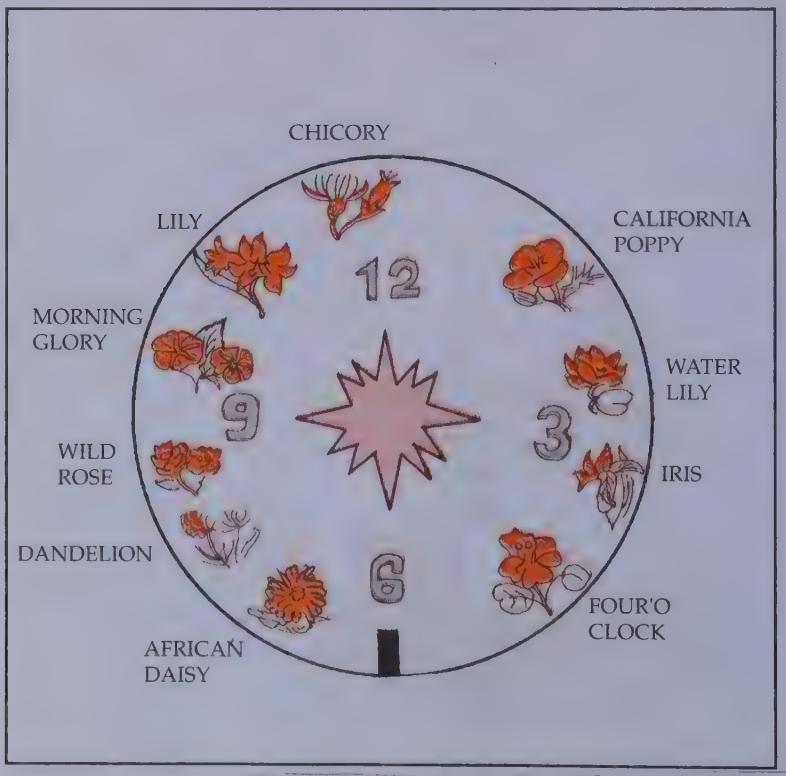

Fig. 2.7: The clock of Linnaeus.

Fig. 2.8: Bee visiting a flower.

Beling trained bees to visit a nectar-feeding station in the evening between 4 p.m. and 6 p.m. The bees did not visit at other times, but they still visited even when the nectar was removed. When outside cues, such as light, were removed in laboratory trials, the bees still fed at prescribed times. Although von Frisch did not know it, the bees were operating on an internal clock.

In 1920, W.W. Garner and H.A. Allard wrote a paper in which they showed that tobacco plants would flower only if exposed to a certain number of hours of light. The term 'photoperiodism' was used to designate the response of the organisms to relative length of day and night. Garner and Allard showed that plants could tell time (Fig. 2.9)! The ability to sense day-length is an important ability for plants so that they grow, reproduce and develop during favourable

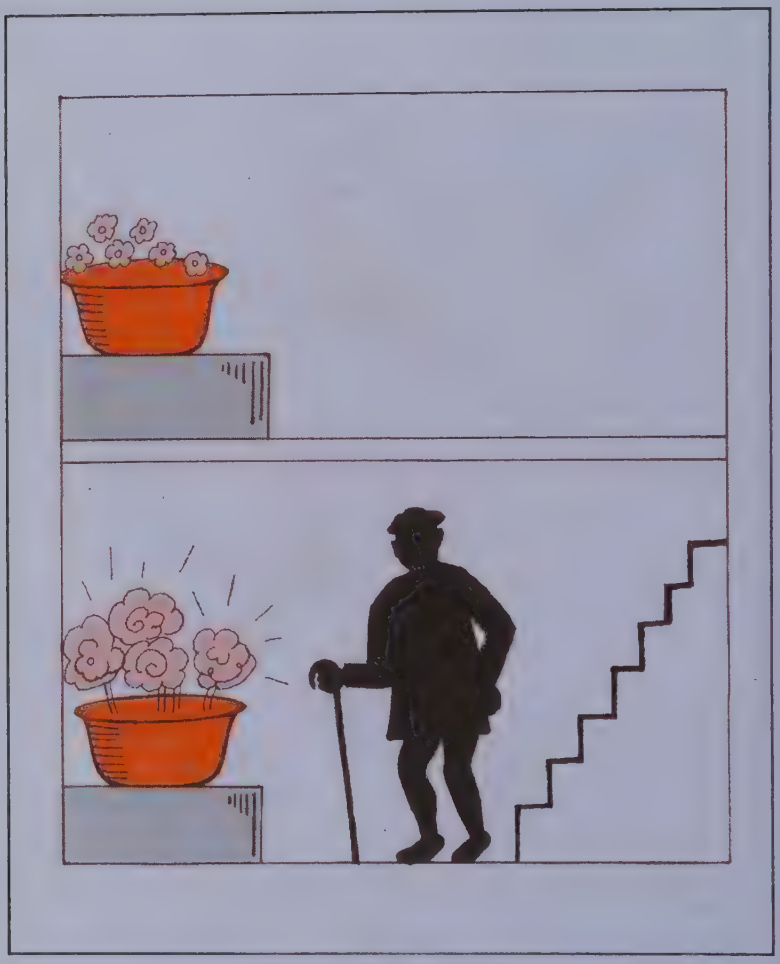

Fig. 2.9: Plants can tell time.

times of the year. The changing times of dawn and dusk contain seasonal information as well as time-of-day information so that the organisms have, in effect, an internal clock and calendar.

It wasn't until the 1950s that two Germans, Gustav Kramer and Klaus Hoffmann, proved the existence of a biological clock. With an ingenious apparatus, Kramer demonstrated that starlings used the Sun as a compass to

migrate even though the Sun itself moves throughout the day. That is, the bird's internal clock reorients it in the direction of the moving Sun. Hoffmann showed that the clock persisted in dim light and thus is endogenous to the animal. He showed that the animal's clock was synchronised to local time by the influence of the local environment. However, some scientists are not yet certain that the biological clock of any organism is completely endogenous. They think that even under the most constant laboratory conditions, living beings are aware of the Earth's rotation and that this has an effect on the 'balance wheel' of their clocks. On the other hand, many scientists, like Hoffman, do believe that such geophysical factors are not essential for the functioning of biological clocks and that the clocks are indeed endogenous.

Around the same time as Kramer and Hoffman, Beatrice Sweeney, a pioneering plant-clock biologist, was able to measure rhythms of oxygen release in individual Gonyaulax (an alga) cells. The alga also exhibits a rhythm of luminescence. The circadian timing mechanism was difficult to determine, until the identification of circadian rhythm genes in Drosophila, the fruit fly, and now in other organisms. Circadian rhythms seem very similar in all species, though it is unclear whether this reflects a common mechanism and hence, a common evolutionary ancestor, or whether an outwardly similar process has arisen several times in evolution. Research scientists have also demonstrated that circadian clocks are temperature-compensated (have nearly the same period even when the temperature changes). Most metabolic activities increase when the body temperature increases, but the period of the biological clock does not. Even in constant darkness, fruit flies emerge on schedule, regardless of the temperature. Thus, temperature changes do not affect the period of the clock.

Today various rhythms have been detected and studied in single-celled organisms such as paramecium, euglena, acetabularia, cyanobacteria and chlamydomonas. Cells from

a variety of organisms are being studied with respect to rhythms in ion exchange, hormone release, and genetic activity.

Photoperiodism

Plants and animals in the temperate zones respond in various ways to the amount of daylight in 24-hour periods. This response to day-length is called 'photoperiodism', which controls many activities, such as migration of birds, hibernation of animals, and flowering of plants. The ability to respond to day-length is linked to an endogenous, or inner, light-sensitive circadian rhythm.

In plants a photoperiodic clock not only controls flowering, but also the induction and termination of dormancy in buds and bulbs, seed germination, and daily rhythms, such as leaf movements, petal movements, and nectar secretion. Changes in relative lengths of day and night also influence the plants that flower once in a year. In the temperate zones, day-lengths during the natural 24-hour cycle vary with the seasons. In summer and spring, the period of light lengthens; in winter and autumn, it shortens. Organisms in these zones undergo alternate 12-hour phases of light sensitivity. During one 12-hour phase, decreasing exposure to light induces a short-day reaction. For example, deciduous trees under the influence of the shorter days of autumn drop their leaves. During the other 12-hour phase, increasing exposure to light induces a long-day reaction. Deciduous trees grow leaves again during the lengthening days of spring. Through their sensitivity to changes in the duration of light, living things can measure day-length to determine the season and the time spans within a season. This fact has helped florists, who often 'trick' their greenhouse plants into producing blossoms out of season by exposing them to unseasonal periods of artificial light.

Characteristics of Circadian Rhythms

Certain similarities occur in the circadian rhythms of most

organisms. For one, frequencies are so precise that the start of each daily activity can often be predicted almost to the minute. In addition, circadian rhythms entrain, or adjust, to an artificial light-dark cycle if the imposed cycle does not vary too much from a 24-hour length. If a test animal is exposed to 11 hours of light and 11 hours of dark in each cycle, its rhythm will entrain; it gets used to the 22-hour cycle. If it is exposed to 13 hours of light and 13 hours of dark, its rhythm will adjust to the 26-hour cycle. But it has been found that even though an organism has been subjected to artificial cycles for weeks, the regular circadian rhythm returns when the artificial one is removed.

A single exposure to light during an extended dark period may 'phase-shift' any circadian rhythm. Because of the exposure, the rhythm may reach its peak at a different time of day, in place of its normal peak time. It will shift from one phase to another. For example, a test mouse kept on a 26-hour cycle in a dark laboratory may begin running its exercise wheel at 10 p.m. on a specific night. But if light is turned on briefly afterwards, the mouse may start running the wheel again at about 11 p.m. on the following night. This is a phase-shift of the circadian rhythm because ordinarily the running activity should begin at 10 p.m. the following night. But instead, the running activity of the mouse shifts from 10 p.m. to 11 p.m.; it begins an hour later. In spite of the phase shift (the displacement of biological rhythm along its time axis), however, the frequency of the rhythm does not change. A 26-hour cycle will remain a 26-hour cycle.

Experimental mice exhibit circadian rhythms under constant laboratory conditions too. Normally, these nocturnal animals begin running on an exercise wheel in their cage at about dusk and then run intermittently throughout the night. During the day they sleep. When their cages are darkened and temperature is held constant, they maintain this circadian pattern in the laboratory, often week after week. Dinoflagellates—plants in natural environment—

show luminescent activity in the sea and emit light at night times alone. Likewise, colonies of the microscopic alga *Gonyaulax polyedra* illuminate ocean waves at certain times of the year. The algae are luminescent at night, especially if the water is agitated, and relatively non-luminescent during the day. This normalcy of rhythms can be altered if these light-darkness conditions are altered or they can be maintained by creating natural light-dark conditions in a laboratory. For instance, creating constant dark laboratory conditions, the circadian rhythm of algae—luminescence and non-luminescence—continues. Ultimately, these plants and animals under experimentation return to their normal circadian rhythms, once the experiments are over.

We already know that temperature does not affect the frequency of a circadian rhythm. And this is true not only for warm-blooded animals but also for cold-blooded animals and plants, whose temperatures change with the surroundings. In warm-blooded animals—the homeotherms, the internal temperature is maintained at a relatively constant temperature through the organism's metabolic activities. A homeotherm's temperature typically does not change in response to changes in environmental temperature fluctuations. In case of poikilotherms—the cold-blooded animals—the internal body temperature varies and remains close to environmental temperature. At cold and hot temperatures alike, circadian rhythms maintain the same frequency. Since such clocks are temperature-compensated, they would not be affected by a wide-ranging temperature change.

Certain rhythmic changes or biological rhythms are not directly connected with external conditions. The urge to eat is one example. You are accustomed to eating at certain times, say, when you feel hungry. This is the time when you may feel the hunger because your stomach is empty. Now, if you do not eat at that time, you do feel miserable, but once that time passes, your hunger may have subsided. This is because the feeling of hunger is actually a product of our bodily rhythms rather than the condition of stomach. Another

example that we can give is of a unicellular organism, the malarial parasite *Plasmodium*, belonging to the phylum Protozoa. All eukaryotes, including *Plasmodium* have biological rhythms. The malarial parasite *P. vivax* shows a 48-hour cycle of multiplication. The attack of malarial fever therefore repeats after an interval of 24 hours, 48 hours or 72 hours, depending upon the species of *Plasmodium*. The fever is the body's response to the process of asexual reproduction by *Plasmodia* within the body that occurs at the same time. The hour of the day when this takes place also remains constant.

Thus, with the possible exception of viruses, every form of life seems to have an internal means of measuring time. These internal 'clocks' do not require the intricate action of muscles or nervous systems since they are found in most one-celled plants and animals. They are probably interlocked by the basic biochemical events within the cells.

Biological Clock in Animals

House sparrows (Fig.2.10) were one of the first animals in which the biological clock was anatomically localised. The

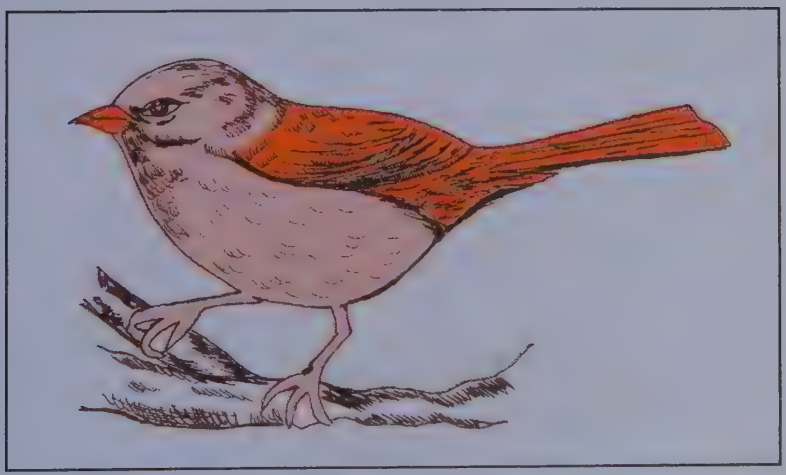

Fig. 2.10: House sparrow, the first animal in which the biological clock was anatomically localised.

sparrow's clock is believed to consist of the supra chiasmatic nucleus (SCN) or a cluster of nerve cells in the brain, and of the pineal gland. In this circadian system, photoreceptors are found in the retina as well as in the pineal gland deep in the brain. Research is underway to clarify the relationship between the SCN, the pineal gland and the photoreceptors in sparrow. The SCN was first identified as a circadian clock in rats. When the researchers spliced the rat SCN, the animal's movements became erratic. This experiment was soon followed by a series of investigations in other rodents and mammals to show that SCN lesions can affect circadian rhythms.

Reptiles (Fig. 2.11) too have photoreceptors in the eye, in the pineal and in the deep brain. Most reptiles and some amphibians, however, also have photoreceptors in the parietal eye, an unseeing third eye located on the top of the skull with a well-defined retina, lens, and cornea that is known to play a role in thermoregulation and photoperiodism. In reptiles and other lower vertebrates, the pineal gland, situated in the back of the head, synthesises information from the photoreceptors and in turn secretes melatonin in a rhythm, which synchronises other parts of the clock system. The pineal gland's secretion of melatonin keeps the animal 'timed' to the environment.

Fig. 2.11: Reptiles have photoreceptors in the eye.

Most animals live under conditions where the day-length and the temperature of the environment change throughout the year. To survive, they must breed at certain times of the year; usually spring or early summer. The offspring will then have a chance to grow strong enough to survive the first winter. The pineal gland keeps track of the changing day-lengths. By means of melatonin, it sends this information to the body and appropriate reproductive responses are made. The role of the SCN in lower vertebrates is unclear, but it is thought to contain a part of the clock.

Since most single-celled organisms have biological clocks that regulate cell division and chemical content, every cell in a many-celled organism probably has them too. However, it seems likely that the biological clocks of only special cells control the time-oriented behaviour of the whole organism. When researchers studying birds assumed that only the retina of the eye perceived changes in day-length—a change that prepares many birds for reproduction, they were surprised to learn that eyeless birds could also respond to changes in day-length. When their heads were hooded, however, the eyeless birds could no longer perceive such changes.

The response of birds to such changes seems to depend on the illumination of the special nerve tissue (encephalic photoreception) either just below the bird's eye sockets or at the edge of the bird's brain. While the growth, behaviour, and general activity of the bird relies on endocrine-gland activity, the initial perception of changes in light and dark is made by a few nerve cells near the bird's eye sockets and these, in turn, influence the bird's entire endocrine system.

Researchers have also pinpointed the presence of biological clocks in invertebrates. And one of the most intensively studied invertebrates is Drosophila, the familiar fruit fly. This insect reproduces quickly, is economical to raise, requires very little space, and has an extensively mapped genome. Mutant strains of flies are presently being used to discover more about the molecular basis of the clock.

While mammals have photoreceptors for controlling circadian rhythms exclusively in the eye, animals such as fruit flies, birds, lizards, and fish have distributed photoreceptors often in directly light-sensitive peripheral organs. In the case of the latter, the clocks are easily 'resettable' when the animals undergo a phase shift or a change in their time schedule. The biological clock has also been found in the optic lobe in other invertebrates, such as cockroaches, crickets and silk moths. Molluscs seem to have a clock only in the eyes. Two types of molluscs: a marine snail (*Bulla gouldiana*), and the sea hare (*Aplysia californica*), have large neurons or nerve cells that can be individually studied.

Mammals such as rats, mice, and hamsters are the most widely studied animals in this regard. All of these rodents have clearly-defined circadian rhythms measured at the onset of their daily movement. Hamsters, for example, are nocturnal and become active at a certain time every night. The rhythm of a hamster can be quantified by recording its activity on a running wheel (Fig. 2.12), which is connected to a computer that converts the raw data into an actogram—a graph that shows the rhythmic activity. In the late 1980s, during a spontaneous mutation process, the *tau* mutant was discovered in a colony of golden hamsters. The period of the mutant gene's rhythm was noticeably shorter than the 24-hour norm. When in normal hamsters, *tau* SCN was transplanted in place of the normal SCN, these animals resumed a circadian

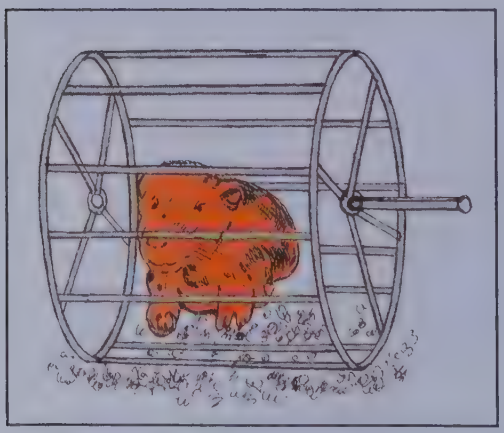

Fig. 2.12: Hamster on a running wheel.

rhythmicity that matched that of the donor. The modified hamsters had a shorter rhythm that was less than 24 hours. This experiment was also repeated in reverse, with the *tau* hamster showing a normal hamster's 24-hour rhythm after receiving a normal hamster's SCN. Thus, experimental proof was available, which confirmed that the SCN is the site of a clock in mammals.

Genetic Control of Biological Clock

Although biological rhythms can be 'reprogrammed' by environmental influences such as when a person regularly works the night shift and sleeps during the day, they are genetically 'hard-wired' into our cells, tissues, and organs. Scientists have learned that specific genes control the function of the biological clock by studying rhythms in mold, flies, mice, and other organisms.

Researchers believe that only a few genes regulate the circadian cycles in most organisms. Mutations in known clock genes usually create large changes in length of the cycle. Organisms with some mutations are unable to maintain any normal rhythm at all. If mutations in human clock genes act in a similar way, they may prevent some people from synchronising their cycles with the environment, causing sleep disturbances and other problems.

At present much clockwork gene research is underway. A research team comprising Kazuhiro Yagita and Hitoshi Okamura of Kobe University School of Medicine, Japan, with Filippo Tamanini of Erasmus University in Rotterdam, have found that the body's peripheral clocks found in the skin and various tissues accurately reflect what is happening in the brain's 'master clock'. Located in the hypothalamus, within the base of the brain, the master clock keeps all peripheral clocks synchronised. All this clockwork is not ticking with an exact 24-hour rhythm, say the scientists, but is reset every day by light. The rhythm is produced by a set of clock genes that switch each other on and off. If you have a missing gene, or have a mutation in one or more of these

clock genes, your clockwork may tick imprecisely—either too fast or too slow or, even worse, it may not tick at all, or it may even stop ticking.

In 1990, a precise shotgun-like technique was used to locate the biological clock gene. The researchers fed, hundreds of mice, food containing a strong chemical that causes mutations or biological changes in genes. The hope was that the chemical would cause a mutation of a bio-clock gene in one of the mice, leading to significant behavioural changes in the affected mice that could in turn be traced back to genes altered by the chemical. The scientists then carefully tracked the mice and their use of their exercise wheels, since normal laboratory mice, following their inherent biological clock, start their exercise wheels at precisely the same time each day. In an amazing stroke of good luck, the 25th mouse under observation began to show up late for its exercise. Upon further study, the scientists discovered that this mouse suddenly had a daily rhythm one hour longer than that of other mice. A single defective gene, which one of the scientists named the 'clock gene', caused the schedule change. Descendants of this mouse bred to have two copies of the defective gene had a daily rhythm four hours longer than normal mice so that they were on a 28-hour cycle.

It was in 1997, that researchers isolated the gene that controls the biological clock of mice. They found that the normal version of the clock gene is made up of 24 segments, called 'exons'. These are the functional parts of the gene—the sections that code for proteins. The mutated gene showed what was essentially the loss of one exon, which, evidently, slowed the bio-clock. The results pointed to the probability that scientists would eventually be able to piece together a basic understanding of life's natural rhythm and the many effects it has on the functions of complex organisms. The mice deprived of a normal copy of the gene lost their 24-hour biological cycling and began to run on a 25-hour cycle instead. Furthermore, when the scientists restored the

normal gene, the mice went back to a 24-hour cycle. A similar gene had been isolated earlier in fruit flies, and in locating the gene in mice, the scientists raised the possibility that such a gene might be found in humans too.

Recent research indicates that the peripheral clocks work just like the master clock, with key genes 'oscillating', amplifying and dampening each other's expression. Working together, clock genes tell the body whether it's time to perk up or chill out, just as a conductor at a music concert sets the pace for musicians performing brisk or slow compositions.

Some clock genes also regulate or stabilise the activity of other genes. The way the clock proteins affect body functions is not yet known. However, learning how normal cycles affect the body may improve the diagnosis of many disorders, such as fever and high blood pressure, by accounting for daily rhythmic variations in hormone levels, blood pressure, temperature, and other traits.

Infradian Rhythms

The worm named Palolo worm, *Eunice viridis*, lives in the shallow waters in the coral reefs of the South Pacific Sea. During its main breeding season, which occurs during the last quarter of the Moon in November, the worms produce segments that are engorged with sperm or eggs. These segments break off at sunrise, rise to the surface, and thrash about. The villagers around the shore rush to the water to scoop up the delicacy—the segments. The gelatinous mass is then baked or fried and eaten. Some villagers are said to be able to predict the swarming to the day.

In the Atlantic Ocean, another marine worm, the Atlantic fire worm, *Odontosyllis*, has a reproductive cycle in which the females rise to the surface and shed eggs while giving off a bright luminous substance. The males return in the direction of the flash and fertilise the eggs. These displays occur once during each lunar cycle of the Moon, on the night before the fourth quarter of the Moon. Perhaps, the bright

light, which Christopher Columbus, the man who discovered America, described on the night of 11 October 1492, might have been the glow of the fire worm because the date is correct for when the worms would be mating.

These are the 'mating' rhythms, which are called 'infradian' or long-period rhythms. Bird migrations, hibernation, the human menstrual cycle, fur colour changes, and reproductive cycles are all infradian rhythms. Although some reproductive cycles, such as that of the 17-year cicada are very long infradian rhythms, we are all familiar with the yearly springtime population boom of animals. Seasonal rhythms such as those that last about a year are called 'circa-annual rhythms' and are usually associated with long-lived plants and animals. These rhythms persist for several cycles and under seasonally constant conditions. It is the photoperiods that trigger most circa-annual rhythms.

Animals change their behaviour according to the season. Phenomena such as reproduction, hibernation, and migration are all based on seasons. It is believed that animals perceive the change of seasons by the patterns of light and dark. The mechanism used to implement this behaviour is by the secretion of the hormone, melatonin, from the pineal gland. When daylight hours grow shorter during the autumn months, melatonin production in animals automatically increases, helping to make the almost constant sleep of hibernation possible. When daylight hours increase during the spring, the pineal gland secretes less melatonin, thereby triggering a new pattern of physical activity.

Reproductive Rhythms in Plants and Animals

Photoperiods control the annual reproductive cycle of certain animals. Many mammals breed during spring and summer. This may be because springtime weather conditions are certainly less harsh than those of winter. For birds availability of appropriate nest sites is yet another factor. Organisms living in a temperate climate synchronise reproduction with favourable environments to maximise their fitness and

survival rate. During the time of birth and feeding of the young, good nutrition is quite important. During spring, plants produce nutritious young shoots and flowers and insects are at their highest numbers. However, although food is the dominating ultimate factor of reproduction, it is not the only one.

There are certain physiological or proximate factors that contribute to seasonal reproduction. For instance, the size of testes of seasonally breeding birds and mammals increases dramatically from the non-breeding to the breeding season. And in male mammals the sexual activity coincides with a rise in the activity of the testes, which in turn is affected by the day-length. Day-length, on the other hand, is known to influence the activity of the pineal gland, which is situated in the brain. The pineal gland secretes melatonin during periods of darkness and is thus sensitive to light and darkness. One theory suggests that the seasonal activity of the pineal gland influences the activity of the testes. Because of this, the testes in spring may secrete more of the sex hormone.

Environmental cues such as temperature, food availability, and social cues do matter but photoperiod is the most important one, at least in males. In animals, gonadal enlargement can be induced during the winter season by keeping the animals under artificial conditions of longer periods of light than darkness. As regards the female mammals, they come into estrus such that the birth occurs during the most convenient environmental conditions.

Phenology

'Phenology' is the study of how certain biological events that depend upon climate take place and how these are affected by seasonal weather changes. The events include the migration of birds, the hibernation of animals, the sprouting and flowering of plants. Farmers and others whose work is affected by weather can use the information to plan their activities. For example, in some areas, alfalfa, a plant,

is ready to be cut about 30 days after the common lilac blooms. Farmers can therefore predict when they will have to cut their alfalfa by observing when the lilac blooms.

Artificial satellites provide data on atmospheric temperatures, solar radiation and the reflection of the Earth's surface. This information helps scientists to detect certain phenological events worldwide. For instance, phenologists use this information to determine when vegetation will become green or turn brown in various regions. The data can then be used to develop mathematical models of the life cycles of plants and animals raised in different climates.

Biological clocks set the schedule for yearly rhythms—the circa-annual rhythms in living beings. They control the sprouting of seeds and the migration and hibernation of birds and animals. These clocks also seem important in helping birds, fishes, crustaceans and insects to navigate. The clocks used in conjunction with the Sun, Moon and stars, help them to correct continuously for the Earth's rotation, and stay on the proper course.

Migration

Periods of migrations date back to 3,000 years. In the Bible in Job (39 : 26), "Doth the hawk fly by thy wisdom and stretch her wings toward the south?" And in Jeremiah (8 : 7), "The stork in the heavens knoweth her appointed time; and the turtledove, and the crane, and the swallow, observe the time of their coming." Aristotle noted that cranes travelled from the steppes of Scythia to the marshes of the headwaters of the Nile.

Circa-annual rhythm is best seen in the migration of birds and animals. Many birds migrate in the fall. "I got rhythm; I got rhythm; I got rhythm; who could ask for anything more?" That's how the song goes and that's how the birds go. Because the trip can be dangerous, some travel in large flocks. For example, geese fly in noisy, V-shaped groups (Fig. 2.13). Other kinds of birds fly alone. Birds can fly very long distances. For example, the longest migration

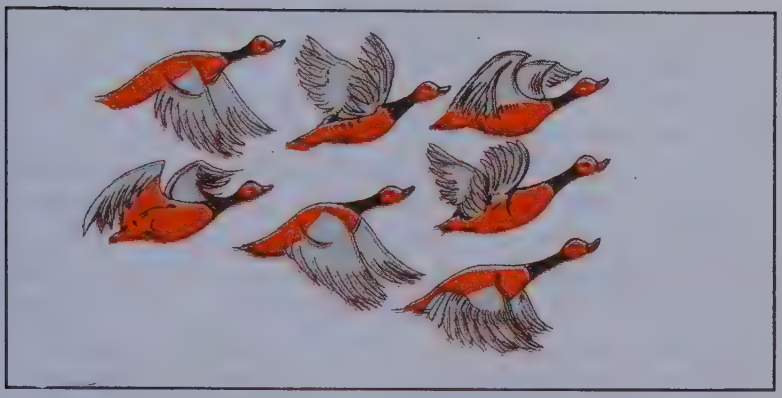

Fig. 2.13: Migrating geese fly in V-shaped groups.

of any known animal is that of the Arctic tern, which travels 15,000 kilometres from the North Pole to the South Pole and back again each year! In autumn, it flies south all the way to Antarctica. Each spring it returns north again. Seagulls and cranes migrate from Siberia to India in every winter and go back in summer season to Siberia. Siberian cranes spend their summer in cold countries in higher latitudes and winter in the warm tropical countries. At the end of autumn, they fly towards the tropics and back towards the higher latitudes at spring. Thus, they enjoy the best environmental conditions at both the places. Most long-distance migrant birds fly at night. They may travel continuously by night and land daily around sunrise to rest and feed.

Birds migrate towards the tropics when days begin to shorten. The return migration begins when the days begin to lengthen. During their annual migrations, some birds fly over vast stretches of water and fly at night when landmarks even are not visible. The golden plover, for example, leaves Alaska in late summer and flies to its winter home in Hawaii. Flying over water for more than 3,200 kilometres, the bird requires pinpoint navigational accuracy to reach the tiny group of islands. Any significant error would cause it to become lost over the Pacific Ocean.

Why do birds migrate? Traveling to different habitats

enables birds to find plenty of food throughout the year. For example, in the winter, when food sources are limited in northern areas, waterfowl such as geese fly south to areas that have mild weather and abundant food.

How do they know when it is time to leave for the winter? Scientists are still studying this. Many see migration as part of a yearly cycle of changes a bird goes through. The cycle is controlled by changes in the amount of daylight and the weather. But how do they find their way to the same place each year? Through a variety of methods birds find their way over vast distances every year. Birds seem to navigate like sailors once did, using the Sun, Moon and star patterns, distinctive smells, and topography landmarks for direction. They also seem to have a compass in their brain for using the Earth's magnetic field.

Weather affects migrating birds' progress. The 'tail winds', the wind at their backs, have to be present. The night sky should be clear showing all the stars, and the temperature should be warm. Snow geese for instance are likely to start flying on such a day. They may then continue to fly day and night no matter what the weather is like until they get to their next stopover point. When they land in a goose-friendly habitat, they feed, rest and wait for good flying weather, usually for a few days. Only if they fly into a bad storm with strong winds in the wrong direction would they 'drop down', or land, in a less than friendly habitat.

Migrating birds react to weather in different ways. For example, small birds would be more likely to drop down if they ran into a rainstorm, because they would expend too much energy flying into the wind. A powerful storm, such as a hurricane can push birds backward on their migration route, or suck them into the eye of the storm. While smaller birds would not survive this, shorebirds and larger birds would hang in there until they get to land, and then drop down to rest and feed.

One of the most important skills of a migratory animal is its ability to tell time. As you will see during the migrations

in spring, there are countless cases where an animal's very survival depends on being at the right place at the right time. To 'tell time', animals use internal timing mechanisms—biological clocks. While the underlying science of biological clocks is complicated and not fully understood, we do know that animals set their master clocks according to the world's most dependable time-keeper—the Sun. The photoperiod, the amount of daylight hours, governs the annual rhythm of life throughout the plant and animal kingdoms. The annual cyclical changes in photoperiod provide a dependable measure of time.

Studies show that the direction-finding ability of animals depends on 'sightings' of the Sun or stars and on the functioning of an internal clock that senses the time of day with some accuracy. The internal clock is vital for navigation because the positions of the Sun and stars are never fixed in the sky. An animal relying on them for navigational purposes would have to know the time between one such position and another in order to maintain its course. A variety of experiments have demonstrated that animals use the Sun and stars for direction-finding. In an interesting experiment scientists captured birds migrating southward at night and brought them to a planetarium. When the star pattern of the local sky was projected on the planetarium ceiling, the birds collected at the south wall, indicating a desire to continue their southward migration. When the pattern was rotated 180 degrees, the birds flocked to the north wall, clearly showing that they determined direction by the position of the stars.

Birds migrating during daytime were caught and put into an outdoor cage where they could see the Sun. They indicated the direction in which they wished to fly by fluttering motions in the cage. When placed indoors and exposed to a light bulb, they moved in the normal direction of migration only when the light bulb was in the same position as the Sun. Whenever the light bulb was moved to a different position, the birds changed their direction.

Honeybees were trained to obtain food at a fixed direction from the hive. They were flown from their New York hive to the one in California where they could get food from any of the group of trays encircling the hive. The bees flew in the direction at which they expected to find food, but it was not the same as the one in which they had been trained to go in New York. Calculations revealed that the difference between the new and the old direction corresponded to the three-hour difference in standard time between the two states.

Thus there is a definite relationship between internal clocks and direction finding. Birds and bees trained to feed at a certain site were exposed to artificial light each day until midnight and then kept in the dark until noon. When they were released in natural daylight, they went in the wrong direction to feed. Scientists could predict the error in direction simply by calculating the extent to which the internal clocks of the birds and bees had been reset.

Other animals, besides birds and bees, migrate too. There are a few mammals, like some bats, caribou and elk, and whales that travel in search of food each winter. Many fish also migrate. They may swim south, or move into deeper, warmer water. Insects too have this direction-finding ability. The food-laden honeybee, for instance, makes a sure shot beeline for its hive. Insects such as butterflies and moths fly very long distances during migration. For example, Monarch butterflies (Fig.2.14) spend the summer in Canada and the northern USA. They migrate as far south as Mexico for the winter. Most scientists think that butterflies use the position of the Sun in the sky

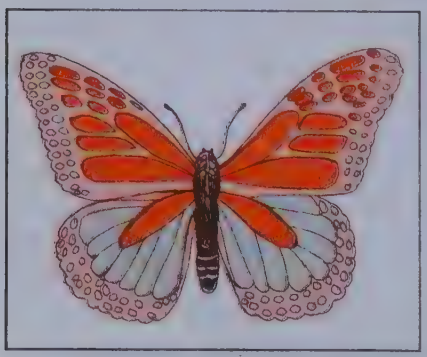

Fig. 2.14: Monarch butterfly.

as a kind of compass that allows them to determine which way is north. They may use other cues, such as the Earth's magnetic field, but we have a lot to learn about the Monarchs' sense of direction. Most migrating insects go much shorter distances. Many, like termites and Japanese beetles, move downward into the soil. Earthworms also move down; some as far as 2 metres below the surface.

Adaptation

Year after year, in a rhythmic fashion, some animals remain and stay active in the winter but they must adapt to the changing weather. Many adapt themselves or make changes in their behaviour or bodies. To keep warm, animals may grow new, thicker fur during the fall. On weasels and snowshoe rabbits, the new fur is white coloured to help them hide in the snow. Food is hard to find in the winter, so animals like squirrels, mice and beavers, gather extra food in the fall and store it, to eat later during the harsh winter. Some, like rabbits and deer, spend the winter looking for moss, twigs, bark and leaves to eat. Other animals eat different kinds of food as the seasons change. The red fox eats fruit and insects in the spring, summer and fall. In the winter, since it cannot find these items, it eats small rodents.

Animals may find winter shelter in holes in the trees or logs, under rocks or leaves, or underground. Some mice even build tunnels through the snow. To try to stay warm, animals like squirrels and mice may huddle close together. Certain spiders and insects may stay active if they live in frost-free areas and can find food to eat. There are a few insects, like the winter stonefly, crane fly, and snow fleas that are normally active in winter.

Many animals need to keep warm (Fig. 2.15), especially the cold-blooded ones like fish, frogs, snakes and turtles have no way to keep warm during the winter. Snakes and many other reptiles find shelter in holes or burrows, and spend the winter inactive, or dormant. This is similar to hibernation. Water makes a good shelter for many animals.

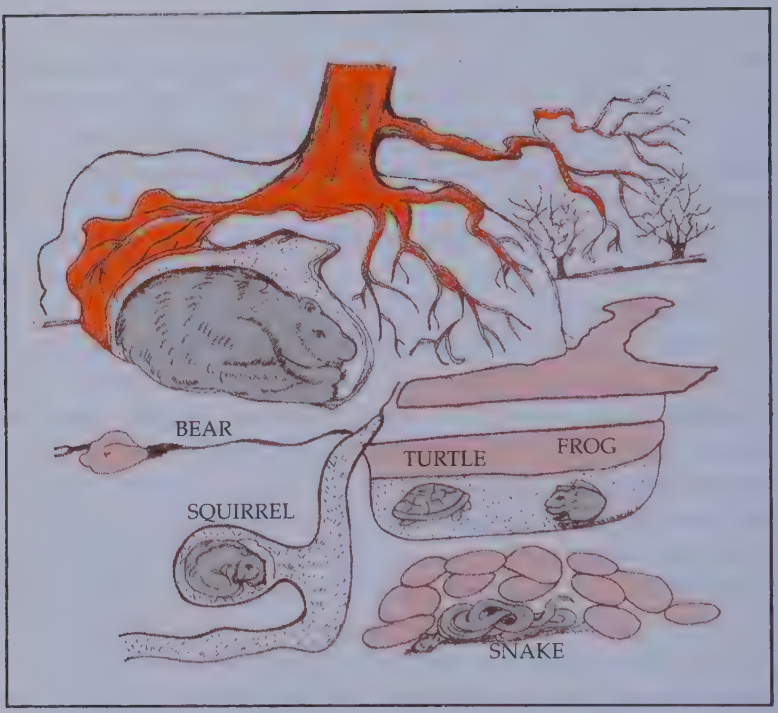

Fig. 2.15: Animals need to keep warm.

When the weather gets cold, they move to the bottom of lakes and ponds. There, frogs, turtles and many fish hide under rocks, logs or fallen leaves. They may even bury themselves in the mud. They become dormant. Cold water holds more oxygen than warm water, and the frogs and turtles can breath by absorbing it through their skin.

Insects look for winter shelter in holes in the ground, under the barks of trees, deep inside rotting logs or in any small crack they can find. One of the most interesting places is in a gall. A gall is a swelling on a plant, which is caused by certain insects, fungi or bacteria. They make a chemical that affects the plant's growth in a small area, forming a lump. The gall becomes its maker's home and food source.

Hibernation

Hibernation is a type of circa-annual rhythm, which is not yet properly understood. It is a peculiarity of warm-blooded animals inhabiting the cold countries. Like migration, this is an adaptation adopted by animals and birds to survive the cold conditions of winter. Some animals hibernate for a part or all of the winter.

Literally speaking, hibernation is the falling of body temperature of an animal (Fig. 2.16) on a seasonal basis,

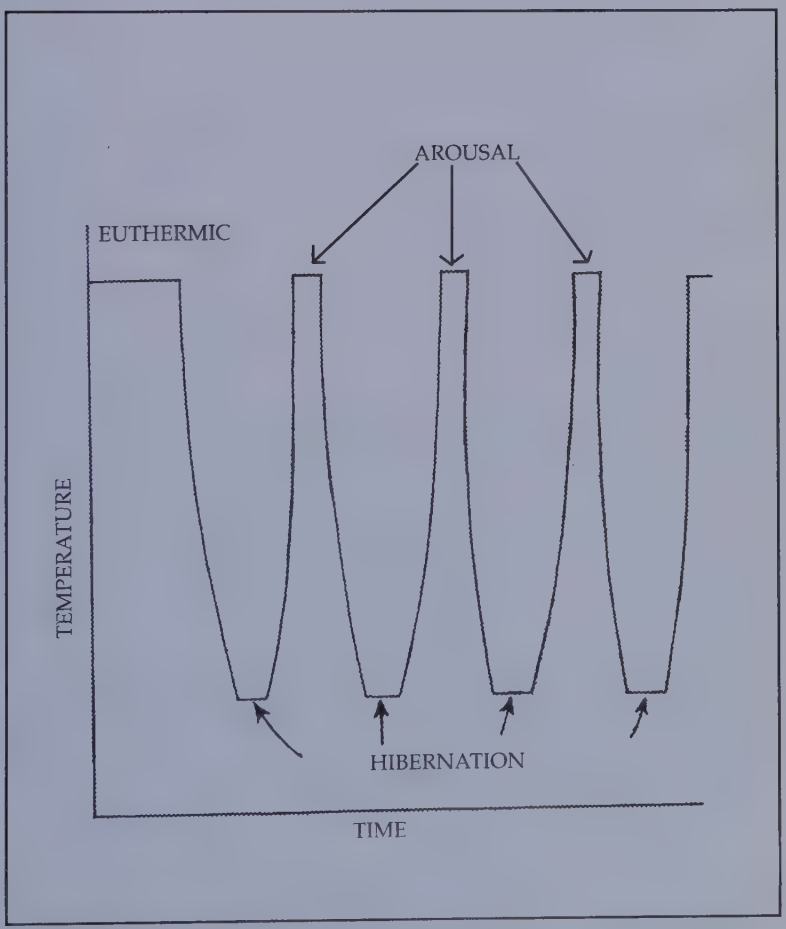

Fig. 2.16: Hibernation curve.

carried out for the purpose of energy conservation. It is obvious that an animal that has some mechanism by which it can avoid winter weather and extreme food shortages would gain a survival feature. The typical behaviour of an animal that hibernates is to have a constant body temperature throughout the season. When conditions are correct, possibly determined by the photoperiod, the warm-blooded animal goes into hibernation and its body temperature drops within a few degrees above ambient temperature. The metabolic rate too drops during the 'winter-sleep' and its heartbeat and breathing slow down. For example, a hibernating woodchuck's heart rate slows from 80 to four beats per minute. The animal uses very little energy. Hibernation, as such is an inactive sleep-like state, lasting the whole winter. In the fall, these animals get ready for winter by eating extra food and storing it as body fat. They use this fat for energy while hibernating. Some also store food like nuts or acorns to eat later in the winter.

Mammals such as bats, bears, skunks, chipmunks, hedgehog and hamster, birds such as swift and invertebrates such as butterflies are known to hibernate in the cold countries. The animals do not really travel large distances to hibernate during migrations. For example, birds may rest in their nests or bears and bats would dwell in their caves and come out of it only after the hibernation period is over.

How does an animal know when to begin hibernation and when to end? A chemical called 'hibernating inducing trigger (HIT)' is present in the blood of hibernating mammals. It is some kind of an opiate, chemically related to morphine. The manufacture of this chemical depends upon the external trigger photoperiods. As the days get shorter, the temperature changes, and food becomes scarce; the HIT triggers hibernation. However, how and why it happens is still a mystery.

It is true that an animal does not hibernate continually through the winter, but has, after a few days or weeks, a period of arousal when the animal's body temperature rises

back to normal. It is a common misconception to think that an animal is sleeping during hibernation. Research suggests that animals do exhibit some of the characteristics of non-REM sleep; however, after studying the EEG and the brain rhythms of a group of hibernators, it was actually found that they were undergoing sleep deprivation and the arousal period appears to compensate for this. After a short time the animal slips back into a state of hibernation and this cyclic behaviour continues until the final arousal time in the spring.

Estivation

Changing seasons can cause the animals to become dormant or get into suspended animation in response to hot, dry conditions. For example, during the hot season you may see snails estivating or lying in a dormant position in the gardens or on a fence-post near your pots in your home garden, surrounding your building. But as soon as monsoon arrives, they start crawling.

Diapause

Every type of insect has its own life cycle, which is the way it grows and changes. Different insects spend the winter in different stages of their lives. Many insects spend the winter dormant, or in 'diapause'. Diapause is like hibernation. It is a time when growth and development stop. The insect's heartbeat, breathing and temperature drop. Some insects spend the winter as worm-like larvae. Others spend the winter as pupae. This is a time when insects change from one form to another. Other insects die after laying eggs in the fall. The eggs hatch into new insects in the spring and everything begins all over again.

Tidal Rhythms

Another type of rhythm seen in organisms is that imposed by the ebb and flow of tides in a sea or an ocean. These rhythmic movements correspond to the high and low tides,

due to movements of the Moon. To understand this rhythm, one must go back to Earth science. The Earth rotates on its axis in a counter-clockwise fashion and the Moon circles the Earth in the same direction. In one Earth rotation (24 hours), relative to the Sun, the Moon moves so much that the Earth has to rotate an additional 13 degrees to 'catch up' with the Moon. As a consequence, the time between a Moonrise to Moonrise on an average is 24 hours and 51 minutes. During this time span, two tidal inundations occur at approximately 12 hours 24 minutes apart. The ebb and flow of the tide imposes alternating fluctuations in temperature, pressure, food supply, mechanical agitation, and salinity on the organisms in the inter-tidal zone. The tide, therefore, often moulds their physiological and behavioural responses into tidal rhythms. These rhythms persist even when the organisms are put in the laboratory environment.

Interesting tidal rhythms can be seen in a flatworm, on the coast of Brittany. The worms migrate to the surface during low tides at daytime, but burrow in the sand during high tide at night. Photosynthetic algae live within the tissues of these worms and it is to the worms' advantage to get as much sunshine as possible. They burrow during high tide to prevent dislodgement. This rhythm persists in the lab when the worms are kept in constant light, but not in constant darkness.

The major effects of the tidal rhythms are found in the organisms that inhabit the shallow waters of the sea. Visitors to the beach may be familiar with the low-tide scurrying of fiddler crabs as they feed, court, and threaten one another. The skin of fiddler crabs normally darkens at dawn and gets pale at dusk. Their running activity adjusts to the tides, which rise and fall about 50 minutes later each day. As high tide approaches, they return to their burrows. Do these crabs simply burrow as they notice the water coming, or do they have an endogenous rhythm synchronised with the tides? Fiddler crabs kept in constant darkness in the laboratory continue to change colour in response to the tides of their

home beach. However, when they are moved to a beach that has different tidal times, they adjust their activities to the new tides. Their biological clocks are automatically reset.

Tidal activity rhythms have also been observed in other marine invertebrates such as isopods, pink shrimp, midges, snails, molluscs and also in fish. Shanny is a fish, which lives under stones in pools during low tide and feeds during high tide. The grunion, a small fish found along the coast of the United States, has monthly or semi-monthly breeding rhythms. From February to September, at maximum high tide, every 14.8 days, grunions ride a wave to the shore. As the wave recedes, the females drop their eggs in the wet sand, and the males fertilise the eggs. The next wave carries the grunions back into the ocean, but the eggs remain on the beach. At the next high tide, 14.8 days later, a wave comes in, breaks the eggs and carries the young fish out to the sea.

In addition to marine animals, tidal rhythms influence the birds as well. Australian reef herons fly from rookeries out to sea to feed on animals exposed during low tide, due to the presence of a clock within.

Latest Research

Today researchers employ a new DNA chip technology to determine how plants use their biological or circadian clocks to anticipate changes in the surrounding environment. A group of scientists at The Scripps Research Institute (TSRI), led by Steve Kay, in collaboration with his colleagues at the Novartis Institute for Functional Genomics in La Jolla, USA, were able to measure the changes in activity of more than 8,000 genes in the mustard weed, *Arabidopsis thaliana*, a model species for plant genetics, to understand the role of clocks in the control of plant growth and development. The completion of the first entire genome sequence of the plant has allowed the researchers to probe into which genes switch on and off in anticipation of environmental changes or during normal development. The research showed that the circadian clock helps to choreograph the complex control of

sugar metabolism, a process vital to plants and, in fact, to all life on Earth. In addition, the scientists found that the clock controls genes implicated in the absorption and utilisation of mineral nutrients, such as sulphur and nitrogen. The circadian clock even co-coordinated the developmental processes, including cell elongation and expansion. These findings provide a potential mechanism for the daily rhythms in leaf movements and flower openings that were first noted in 4th century B.C. and have been studied by many eminent scientists, including Charles Darwin.

Researchers have discovered many of the components of the clock mechanisms that operate in organisms ranging from bacteria to humans. A major mystery that has remained is the identity of the light-capturing molecules that transmit the light signal to the clock. A light-absorbing protein, called 'cryptochrome', may play a role in organisms ranging from plants to mammals. The protein, which is sensitive to blue light, is important for a variety of light-based growth responses in plants, such as bending towards light. Just finding that cryptochrome plays a role in clocks ranging cross-kingdom from plants to mammals is an amazing development because, besides filling a gap in our knowledge of circadian clocks, the work could also lead to new remedies for jet lag in humans that might mimic or enhance the process by which light resets the clock mechanism.

That mechanism, the biological equivalent of the gears and springs in a watch, is a set of proteins whose levels rise and fall in a daily cycle. The proteins regulate their own oscillations by turning their own genes on and off; light can shift, reset or 'entrain' a clock by raising or lowering the level of a key clock protein and so influencing that feedback process.

The molecular homology between the fruit fly and mammal is no doubt stunning. Similarities on a 'systems wide' level, however, remain uncertain. Although investigators have known for some time that circadian oscillators exist throughout the bodies of several animals, researchers

are only now starting to understand how the well-characterised mammalian, supra chiasmatic nucleus (SCN), about which we shall discuss in our later chapters, co-operates with the body's peripheral clocks. Only if scientists could identify the signals that put the SCN in touch with peripheral oscillators, they might be able to fashion a treatment by manipulating these signals. Although scientists guess that the signals could involve hormones, the actual mode of communication remains a mystery and continues to be the focus of a hot area of circadian research.

Molecular biologists have been trying to analyse the intricate innards of organisms' biological clocks for decades, gaining rare insight into a veritable bridge between genes and behaviour. Those clocks' circadian rhythms, the 24-hour cycles that govern physiological and metabolic functions, enable organisms to follow the outside world's cues of light and dark. Interest in circadian rhythms is due not only to their practical applications, but also because they have an intrinsic appeal as an unparalleled window on the phylogeny of several animals. Thus, by far, homology among animals, cyanobacteria, fungi, and plants appears relatively limited, suggesting that each has evolved independently. But investigators have uncovered a remarkable and fascinating degree of conservation among the molecular players driving the clocks in animals, from fruit flies to humans. Yet, even here, as researchers continue to explore the more complex mammalian system, significant areas of divergence, perhaps most notably between the oft-compared mouse and fruit fly, are starting to emerge, especially with regard to the co-ordination between cellular clocks in the brain and the rest of the body.

3

THE HUMAN CLOCK

To every thing there is a season, and a time to every purpose under the heaven—a time to be born, and a time to die, as well as a time to heal.

—Ecclesiastes

Biorhythms

Throughout the ages humans have been intrigued by the effect of the Sun, Moon, and stars on their daily lives. The day-night cycle and seasonal changes have been the fountainhead of religious beliefs and scientific inquiry as long as humans have inhabited the Earth. You arrive in a new time-zone, go to a hotel, and wake up after a long, disorienting sleep. How do you tell if it's day or night? Light is a good cue, and not just for your mind. Deep in your brain, a molecular clock (Fig. 3.1) that oscillates with a 24-hour

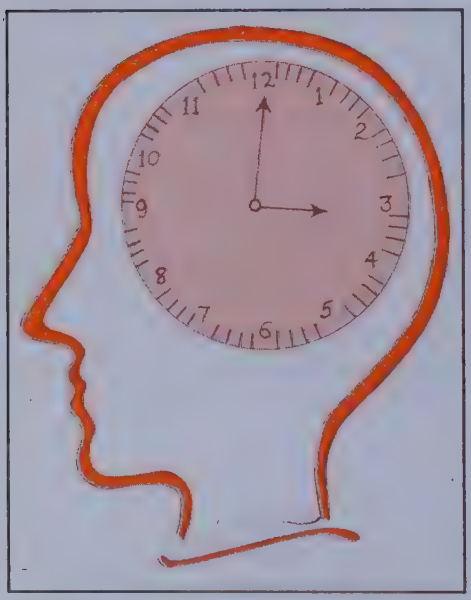

Fig. 3.1: Clock is situated in the brain.

rhythm, pacing your physiology, also relies on light to keep it in sync with the day-night cycle.

Only recently have we attained a deeper understanding of biological rhythms or biorhythms that regulate human existence (Fig.3.2). As long as 3,000 years ago, the scientists of ancient Greece were recording the regular rhythms of basic bodily functions such as respiration, kidney activity, pulse rate and, of course, the female menstrual cycle. These rhythmic cycles affect even the tiniest cells of our body from the day we are born to the day we die. Hippocrates, the celebrated Greek physician, noticed that good and bad days fluctuated cyclically in both sick and healthy people. It was only relatively recently, however, that the theory of three internal cycles with a definite effect on behaviour patterns gained credibility in our society, and people in all walks of life appreciated its practical use.

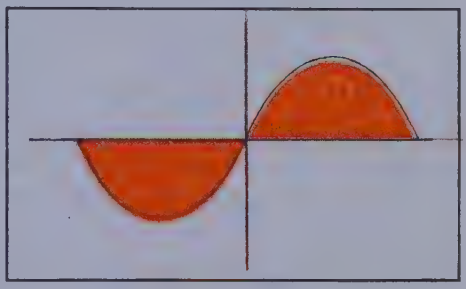

Fig. 3.2: Graphic representation of a rhythm.

Years ago, a German physician in Berlin, Wilhelm Fliess, provided the first tentative explanation for this phenomenon, on the basis of physiological and emotional cycles. Later, an Austrian physician, Prof. Alfred Telcher, further developed the theory identifying a third component, the intellectual cycle. In 1900, Hermanna Swoboda, a professor of psychology at the University of Vienna who took an interest in human cycles, wrote: "Life is subject to consistent changes. This understanding does not refer to changes in our destiny or to changes that take place in the course of life. Even if someone lived a life entirely free of outside forces, of anything that could alter his mental and physical state, still his life would not be identical from day to day. The best of physical health does not prevent us from feeling

ill sometimes, or less happy than usual." Analysing dreams, ideas and creative impulses of his patients, Swoboda noticed regular patters or rhythms. For instance, expecting mothers begin to show anxiety about their infants whenever the critical day of giving birth occurs or was about to occur. He went on to write books explaining and developing ideas of human cycles.

Biorhythms are the natural ups and downs—fluctuations that govern the physical aspects of the body, the emotional cycles and the intellectual cycles within the brain. The physical aspect encompasses one's energy levels, resistance, and overall physical strength and endurance. The positive half of a cycle is when we feel we are at our best. This cycle influences physical factors such as eye-hand co-ordination, strength, endurance, and resistance to disease. There will be a peak time when we can feel physically fit to work on projects requiring physical strength and endurance, while during the down half of cycle we are likely to have less energy and less vitality.

The emotional cycle governs the nervous system and is also referred to as the 'sensitivity rhythm'. This cycle influences our emotional states, affecting love/hate, optimism/pessimism, passion/coldness, and depression/elation. The peak comes when we are feeling most creative, most loving and warm, and we are probably more open in our relationships. During the low period we are more inclined to be withdrawn and less co-operative. We may also be very irritated and negative about those things that occur in our everyday life.

The intellectual cycle supposedly originates in the brain. It influences our memory, alertness, speed of learning, reasoning ability, and accuracy of computation. The peak is when we are considered to be at our most intellectually responsive, and we are open to accepting and understanding new ideas, theories and approaches. During low times we are much more likely to have difficulty in grasping new ideas and concepts.

Newer theories suggest that biorhythms also include our intuitive or psychic cycle. This is a 38-day rhythm cycle that coincides with Greek philosopher Plato's 'four aspects' and with Carl Jung's 'four functions'. Jung, the world-famous psychologist and teacher, described the four functions as sensation, thinking, feeling and intuition. These four functions directly relate to our regular four biorhythm cycles—the physical, intellectual, emotional and intuitional cycles. These work together to regulate our physical and mental abilities and well-being. The fourth cycle controls subconscious perception, hunches, instincts and the 'sixth sense' that relies upon our subconscious abilities, such as telepathy, healing at a distance, Reiki, dowsing, strengthening psychic ability, healing ourself or simply 'mind control'.

Circadian Rhythms

A better understanding of the 24-hour circadian rhythms promises to shed light on the mechanics of sleeping disorders, to help optimise drug delivery, to help night shifters improve alertness, and to elucidate the anatomy of seasonal affective disorders and manic depressive illness because it touches almost every aspect of biology. Its potential applications extend beyond humans, to plants and animals, whose photoperiodism might one day be adjustable so that they seed or breed according to farmers' needs.

Demonstrating circadian rhythms in plants and animals was comparatively easier than in humans for researchers. This is because we humans also possess several internal rhythms and cycles that are in accordance with the 24-hour day and night fluctuations. Sanctorius, a colleague of Galileo, the famous astronomer who loved to perform bizarre experiments, built an enormous balance with a huge platform on which he constructed an entire room in the year 1657. He furnished the room with a chair, a table and a bed. Sanctorius lived on this platform for several days. The crude device even jiggled when he moved about. He began recording his daily and weekly changes in the body weight

while he lived on this platform. He discovered from this experiment that he weighed less at certain times of the day. This circadian rhythm in the body weight, he suggested, was due to loss of water through perspiration.

Briton Davy, an English researcher, 200 years later, recorded his body temperature over the course of several days and over a period of one year. His recordings suggested that the human body temperature rises and falls throughout the day (Fig. 3.3). Scientists later confirmed his findings and

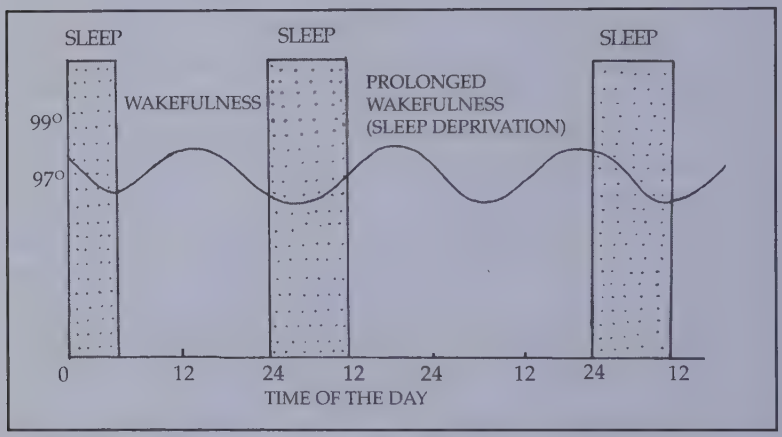

Fig. 3.3: Graphic representation of an individual's body temperature through day and night.

revealed that the body temperature rises to about 99.0°C by evening and drops to a low of about 97°C in the early morning. The temperature remains around 98.6°C during the rest of the day. Not only our body temperature but our heartbeat too does not remain constant throughout the day. Over the stretch of 24 hours, the human heartbeat fluctuates by as much as 20 to 30 beats per minute. Likewise, hormonal levels fluctuate, muscle contractions vary; virtually every body function shows a circadian rhythm. For example, our handgrip is strongest around 6 p.m. in the evening and is weakest at around 3 a.m. in the morning. So, if we happen to meet our boss around 6 p.m. and shake hands, we will present ourselves as very confident personalities.

The cells within our body too show circadian rhythms. Based on this fact, one can identify any unusual or abnormal activity within the cells. For instance, cancerous cells in the breast speed up their activities every 20 hours, instead of the normal 24 hours. The skin cells, the cells in the digestive tract, all work according to the body clock. Due to the activity of cancerous skin cells in the breast, the surface temperature often helps in detecting the disease.

Why is it that we wake up in the morning with a slimy film on our teeth and usually with bad breath? This is precisely because saliva secretion in the mouth is much less during the night as compared to that secreted during the day. The bacteria that grow on our teeth seem to know this fact; hence, they divide much rapidly during the night while we are asleep. Their frantic activity goes unnoticed. The body's enzymes break down faster during one part of the day than another. The activity of enzymes that break down the drugs and toxins we ingest speeds up at 2 in the morning while it slows down some 12 hours later. Similarly, there are enzymes that break up at other hours during the day or in the night. The body clock affects them too.

Most, if not all, organisms have more than one circadian rhythm. Human circadian rhythms include the wake-sleep cycle, glandular secretion, the highs and lows in body temperature, and the excretion of urine. Many studies of persons who have lived for a long time in Arctic regions, where there is continual daylight in summer, have confirmed the existence of these rhythms. Confirmation has also been provided by experimental studies, such as those made of persons living in caves under artificial conditions.

Circadian rhythms are known to re-phase when a person flies across many time-zones in a day. On reaching their destinations, travellers are under new local time, and it takes a few days for their bodies to adjust to the new day-night patterns. This phenomenon is commonly called 'jet lag'. Frequent shifts in circadian patterns, as when a person takes several transatlantic flights in a month, can lead to

mental and physical fatigue. Studies of airline pilots and flight attendants who often travel across many time-zones have revealed that body functions in some individuals become irregular. Other studies have shown that the human body can learn to function in cycles ranging from 18 to 28 hours. Any variance greater or less than this, however, usually causes the body to revert to a 24-hour cycle.

In outer space, daylight patterns are not consistent. Astronauts first encounter rapid changes in the day-night cycle while orbiting the Earth; farther out, there is constant blackness. To avoid disrupting their natural circadian rhythms, astronauts follow regimented cycles established to simulate the 24-hour day. Scientists are conducting studies to investigate what effect future space flights will have on astronauts compelled to live for a long time under artificial conditions.

Circa-annual Rhythms

'Circa-annual rhythms' are those that may occur throughout the year. Clinical studies of blood cells and blood components in humans have revealed circa-annual changes in the volume of red blood cells, haemoglobin, white blood cell function, blood clotting proteins, tumour marking proteins in cancer patients, hormone receptors on blood cells, blood protein levels and cholesterol levels in different blood fractions. Human brain activities also show circa-annual cycles. Circa-annual rhythms have been reported for the amount and percent of REM-sleep, the serotonin-neurotransmitter (brain chemicals) system in the brain, the occurrence of migraine attacks and even the size of hormone vasopressin-secreting neurons in the supra chiasmatic nucleus (SCN); the nucleus that appears to control circa-annual cycles.

Normal individuals appear to have circa-annual changes in basal metabolism, energy level and appetite, as well as in metabolic hormones, like prolactin. Seasonal changes also occur in blood pressure, the incidence of stroke

and the secretion of kidney and adrenal hormones—renin and aldosterone that greatly affect blood pressure. They even exist for the major adrenal stress hormone—cortisol, thyroid gland secretion and secretion of the pituitary hormone that controls the thyroid gland. Reproductive functions too show circa-annual cycles. Men have circa-annual rhythms in testosterone, pituitary hormones controlling testes activity, sperm count and semen chemistry. Circa-annual patterns have been reported for the level of hormone receptors in breast cancer, for the occurrence of premature births and for the chemistry of the fluid in ovarian follicles. Mental health also has a seasonal component, as seen in the winter mental depression of seasonal affective disorder (SAD), sufferers of which have profound seasonal changes in taste sensation, appetite and food intake.

Ultradian Rhythms

It is true that within humans, daily cycles of wakefulness and sleep follow a basic 24-hour cycle or circadian rhythm. However, within the sleep portion of this cycle, another type of rhythm, an ultradian rhythm exists. An ultradian rhythm is a biological rhythm that occurs with a frequency of less than 24 hours. For instance, hormones and the endocrine system exhibit a circadian rhythm. However, if one takes a closer look at many of these hormones, it becomes apparent that they too exhibit an ultradian rhythm. Most hormones are secreted into the bloodstream in a pulsatile manner rather than in a continuous fashion. This is not to say that a hormone cannot have a peak or average plasma concentration that persists at one point in the day more than any other moment. Just as you have 90-minute sleep cycles with the period of sleep/wakefulness, so does a hormone. It can have a group of individual pulses making a smaller part of the overall circadian cycle. Growth hormone (GH) in humans would be a good example of this. It has a pulse, a sudden rise in the hormone levels every three hours, yet overall its period of highest concentration is found at night.

Growth hormone also shows rhythms prior to puberty. Many other hormones, such as adreno-corticotrophic hormone (ACTH), cortisol, and thyroid stimulating hormone (TSH) show circadian rhythms. Cortisol, for example, peaks in the last hours of sleep and hormone, melatonin, similarly shows markedly increased levels during sleep. Thyroid secretion is usually higher in winter than in summer. The menstrual cycle is controlled by a number of hormones secreted in a cyclical fashion. Childbirth is also hormonally controlled.

All these rhythms in human beings are under the control of a 'human clock'. This is the biological clock that controls the rhythmic happenings in our body. It is a kind of clock that works just as a time-piece that times all the activities in our body. If we look into the working of our body, we see that our body is literally awash with internal clocks. Researchers know of over one hundred clocks so far. The human body has inner clocks in nearly every organ, every type of tissue, and inside many cells. All of these clocks have to be synchronised, and all are controlled (and influence) the body's master clock. Chronobiologists—the scientists who study time—divide the human body clocks into three areas: ultradian rhythms (those shorter than a day), circadian rhythms (24-hour cycles) and infradian rhythms (those cycling in intervals greater than 24 hours). Heartbeats, body temperature, breathing patterns, and eye-blink rates are examples of ultradian rhythms. The day/night cycle is circadian. A woman's menstrual cycle is infradian. Hormones released by internal body clocks govern all of these cycles.

Human Biological Clock

A wristwatch tells only one kind of time—world time (Fig.3.4). You must stick to the world time if you have to catch a flight, or you have to catch a train in the morning, or want to see the nine o'clock news. But no wristwatch can tell when you think fastest, add numbers best, or swing a

tennis racquet most deftly. A glance at your watch might make you think now is the 'time to eat', or 'time for bed', even if your stomach is not rumbling, or you have not started to yawn. Feeling hungry or sleepy, however, requires a watchful brain, a brain with its own clock. 'The biological clock'—a hard-wired programme is situated in the brain, that ties our daily behaviour to the rhythms of Earth and the Sun and runs in the background of our life, adjusting automatically, as circumstances demand.

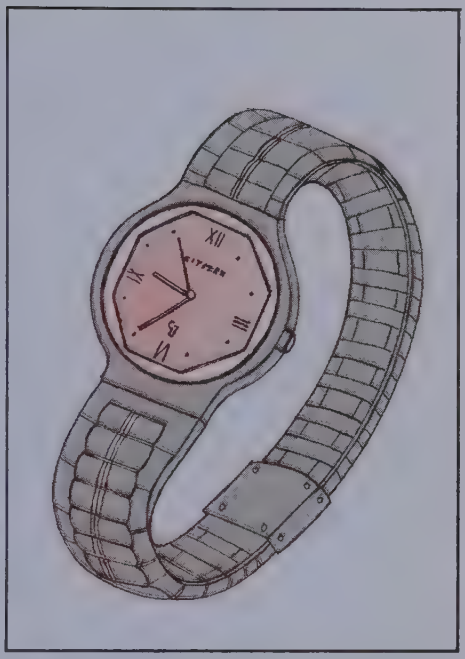

Fig. 3.4: A wristwatch tells world time.

Most of us think we run our lives by the world's clock. Indeed, we often protest that this clock runs us, griping, as did playwright William Shakespeare's in his drama *King Richard III*, "Time is wasting me." Life in the fast track both seduces and enslaves us. While we drive, we gulp cold drinks, soda or tea and coffee, gobble fast-food meals, and gab on the phone. We have no time for relaxing. Life totally revolves around cell-phones and mobiles. We see people chatting on the cell-phone in almost every nook and corner. At work too, we churn out faxes and E-mail, sometimes even to the person in the office next door. Cyber cafes, Internet, Fax, DVDs are in now. We have timed our pace to Internet time, fretting at the few seconds' delay signalled by the icon on our computer screens depicting the now obsolete

hourglass (Fig. 1.7). We are under the sway of what Stephen Bertman, author of *Hyperculture*, calls 'the power of now'. We mimic the March hare, constantly complaining, "I'm late. I'm late, for a very important date!".

Recognition that night-time is the right time for sleep has faded with the availability of Internet with chatting facilities, hundreds of television channels at any hour, partying through the night and the ease of ordering pizza round the clock in the city and suburbs. If we cannot fall asleep or stay asleep, or cannot get going in the morning, we grumble about bad sleep, but the real problem may be bad timing. Most people do not know that they can fix this broken clock themselves. The brain's clock governs whether or not we are grumpy before we have our morning coffee, how quickly we can write a letter and how accurately we can proof-read it, how long it takes us to drive a car 10 kilometres, whether or not we fall asleep at a music concert, when our ulcers cause trouble, and more. Like the crocodile in *Peter Pan*, we carry this clock around, inside of us. The irony is that many of us do not hear it tick.

The central nervous system (CNS), which includes the brain, is responsible not only for the co-ordination of adaptive processes of organisms to their milieu in terms of space, but also organises adaptation 'in time'. All rhythms are controlled by the 'biological clock' in the brain. A tiny sliver of brain tissue, less than the size of a pinhead, regulates the timing of our bodies. Within this sliver lies a biological clock that keeps track of the time of day, and seasons of the year, and marches our bodies and brains in step.

Story of the Clock

It was in the 1920's that scientist and biologist Curt Richter from John Hopkins University in Maryland, USA, observed during his experiments in rats, that the animals persisted to eat at night and sleep during the afternoon in spite of his keeping the room lights off for several days. The rats were displaying circadian rhythms, but what was it that controlled

these rhythms and where was it situated, wondered Richter! The biologist did not give up; he sliced a small bit of the brain tissue of the rat, and still the rat displayed its rhythm. He then sliced yet another bit of the brain tissue and continued his experiment until one day he sliced into the hypothalamus, situated near the base of the brain; he found amazing results. Following the operation, after a day or two, the rats ate at all times of the day and slept erratically. They did not show any circadian rhythm.

Richter further examined the tissue that he had removed and found that it contained a cluster of nerve cells that were located directly above the crossing of the optic nerves, called the *chiasma opticum*, behind the back of the eyes and at the base of the brain. The location of the cells gave them its name, the 'supra chiasmatic nucleus', or SCN. Richter's work went unnoticed until 1972, when two scientists, Fred Stephan and Irving Zucker, both from University of California, USA, sliced into the SCN of experimental rats, ripping off its connection with the brain. This was when they discovered that these rats too lost their circadian rhythms. In other group of animals the researchers, keeping the SCN attached, severed the optic nerve, essentially blinding them. Interestingly the rats showed circadian rhythms even without the optic nerve being present.

In 1977, William Schwartz and Harold Gainer of the National Institute of Health, USA, whilst working on measurement of the activity of nerve cells in the brain of rats, found that the cells were active during the day but inactive at night, proving that the cells of the SCN did have a circadian rhythm of their own. Encouraged by this revelation, two Japanese scientists, Shin-ichi Inouye and Hiroshi Kawamura from the Mitsubishi Institute near Tokyo, Japan, set out to prove that the SCN directs the rhythms by its own action without receiving instructions from any other part of the brain. When they sliced through the SCN, severing its connection with the rest of the brain, every part

of the brain except SCN showed no circadian rhythms. The Japanese scientists confirmed the fact that Richter had suggested 60 years earlier that SCN indeed is the 'master clock'.

SCN—'Master Clock'

The SCN is the biological clock that is located just above where the broad optic nerve trunks cross over each other on their way back from the eyes to the visual centre of the brain. Deep within the brain, inside the hypothalamus, thus lies SCN consisting of two clusters of neurons (Fig. 3.5). Each of these SCN clusters is composed of more than 8,000 neurons. The SCN act as the body's circadian pacemaker. In mammals, SCN appears to get its information from

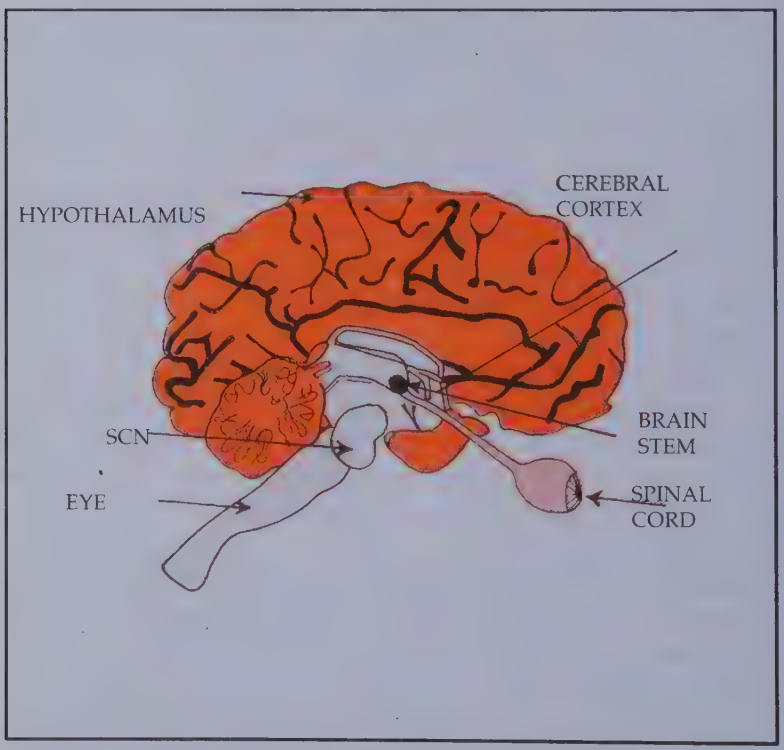

Fig. 3.5: Supra chiasmatic nucleus (SCN).

photoreceptors in the retina, which transmit signals about light and dark through the optic nerves, to the hypothalamus. Once these messages enter the SCN, a series of physiological reactions takes place.

The SCN receives information about light and dark from the eyes, but it has its own dedicated pathway of nerves, the 'retino-hypothalamic tract' (RHT), which is separate from the main nerve bundles carrying visual information to the brain. Light causes the brain's internal clock to reset its cycle (Fig. 3.6). Because of lack of sight and in turn, the perception of light, blind people often report problems with circadian rhythms, since it is difficult for them to get the time cues needed to set their circadian rhythm. Sunlight, reaching photoreceptors in the retina, travels to the brain by the optic nerve. It sets off reactions in the SCN. Circadian changes in the SCN affect the nervous system and cause daily fluctuations in many body traits. Nerve fibres also carry signals from the SCN to the pineal gland, which affects hormones and other functions. We are now certain that SCN is the biological clock, because when it is destroyed in an experimental animal by surgical pinpoint lesions of the brain, the 'sleep-wake' and many other rhythms fade away.

Interestingly, the animal, minus its SCN, runs, eats and drinks the same total amount each 24 hours, but these activities are now randomly distributed throughout the day and night. One final fact about human biological clocks is that they actually follow a pattern of about 25 hours. Hence, if someone lives in a cave or an apartment without windows (as people have done), their circadian patterns of sleep and wakefulness shift 'westward' by about one hour a day. However, in the regular world, sunlight and darkness serve to 'reset' the biological clock every day and keep us on a 24-hour cycle.

Human volunteers at one time were made to live for upto six months in special apartments without windows, telephones, television, radio or any contact with the outside

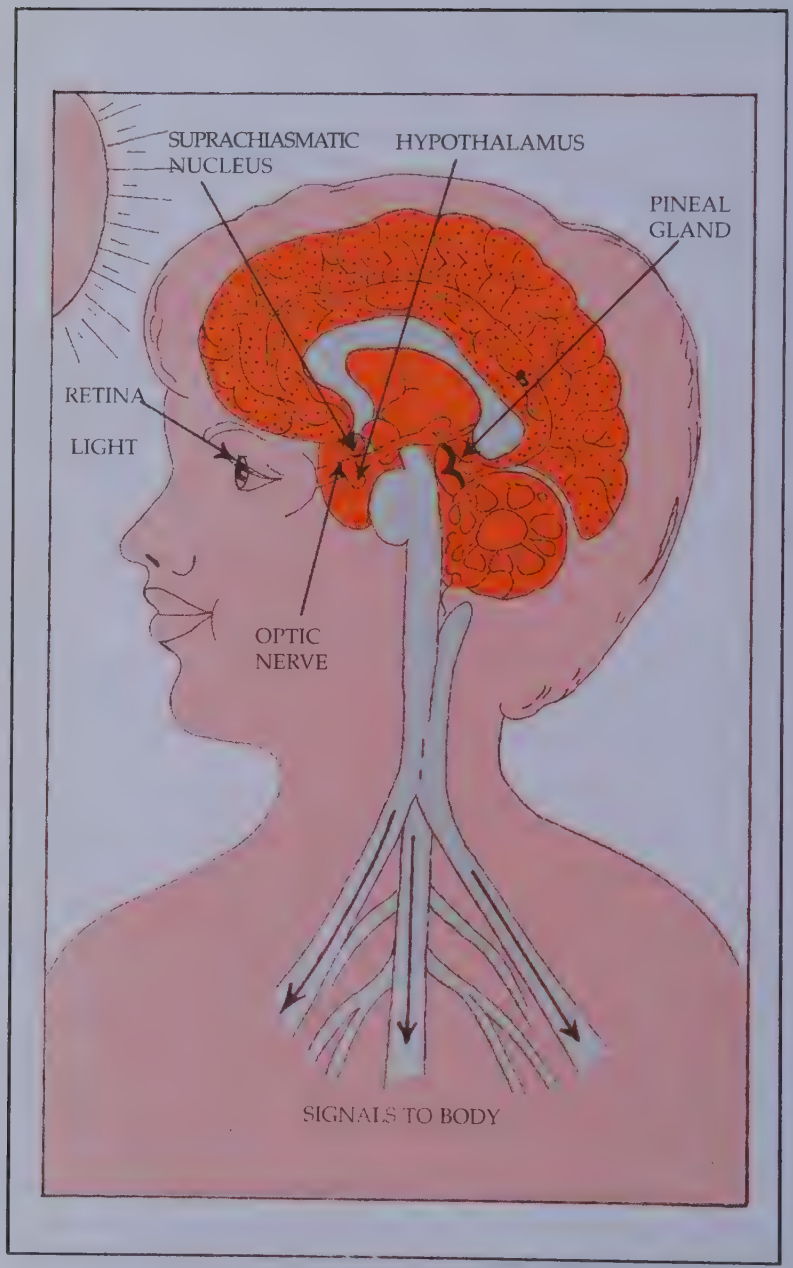

Fig. 3.6: Mechanism of SCN.

world that might provide a clue to the time of day. Under these conditions, the diurnal rhythms regulated by the circadian clock of sleep, activity, body temperature, hormone secretion and a range of other variables persisted, but they no longer exhibited a period length of 24 hours. In the case of a typical person, the 'free-running period' of the circadian system was greater than 24 hours, usually nearer to 25 hours. A rhythmic organisation of activity persisted even in the absence of environmental time cues, collectively termed *zeitgebers*. In the absence of periodic time cues, the period length of the activity rhythm (the time from the onset of one bout of activity to the next) was significantly different from 24 hours. This non-24-hour-period length, which is a consistent feature of diurnal rhythms when observed in the absence of *zeitgebers*, is the origin of the term *circadian*.

The precise circadian period length therefore varies from species to species and between individuals within a given species to a lesser degree. Entrainment to the 24-hour environmental cycle results from daily resetting in response to the *zeitgeber* signal. Entrainment is the ability of the body's internal clock to reset itself to external cues. For example, an individual with an intrinsic period length of 25 hours needs a correction of one hour per day to be entrained to the 24-hour day. Entrainment involves synchronising the period of the circadian rhythm to the period of the *zeitgeber* and the rhythm.

Thus, most humans have a natural periodicity of approximately 25 hours, which can be easily entrained to the 24-hour day. However, in insomniacs and individuals with sleep disorders, something may be wrong with either the entrainment mechanism or the innate oscillation so that their bodies cannot oscillate in synchrony with their environment. The 25-hour period of our internal clock accounts for two maladies which are common in the lives of almost everyone in our modern society. The first is the infamous 'jet lag', which is a circadian disorder that results from changing time-zones (and *zeitgeber* orientation) faster

than the internal circadian clock can adjust. The second common circadian disorder has been termed the 'Monday morning blues'. An individual who sleeps late on Saturday morning misses the normal early morning *zeitgeber* signal and as a consequence, the 25-hour internal clock drifts approximately one hour later. The process is repeated on Sunday morning so that when the alarm clock rings at 6 a.m. on Monday morning, the body's clock is two hours behind and one has to struggle to get out of bed, because it is 4 a.m., according to the body's internal clock.

Recently, scientists have found that the body clock remains constant throughout life. Young people have the same body clock-length as the elderly. Their recent calculations show that the body's internal clock works on a cycle of 24 hours and 11 minutes, to be exact, as against the previous studies that concluded that our body clock worked on a 25-hour period that shortened with age. A study, funded by the US National Institutes for Health, has found both older and younger healthy people share the same circadian period of a little more than 24 hours. This is despite the fact that older people tend to wake up early.

We now know that the SCN is only one part of the mechanism by which the 'time' is kept. There are light receptors found in the retina, which have a pathway, the RHT, leading to the SCN. In humans, serotonin, a neurotransmitter in the brain, which is induced by light, wakes and energises, whereas melatonin, induced by darkness, puts us to sleep. Both are naturally-occurring chemicals whose production is controlled by the pineal, a gland deep in the centre of the brain. When the eye, even with eyelids closed, perceives specific levels of light, the brain's pineal gland triggers the production of certain hormones. An increased level of light triggers the production of serotonin, causing the human body to awaken. At the other end of the circadian scale, the pineal gland, in response to darkness, triggers the production of the hormone, melatonin. This is what causes us to fall asleep.

In order to understand the mechanism of the effect of light on our mind, it is necessary to get an understanding of how our body and brain work. Our brain manages a number of complicated body processes—breathing, digestion, circulation, growth, reproduction, and repair and it utilises two separate systems to control these processes—the nervous system and the endocrine system. The nervous system employs electrical impulses that travel through nerve cells as fast as 200 metres per second to send out messages. The endocrine system on the other hand, sends messages that travel through the bloodstream to produce more long-lasting effects. Endocrine system is a collection of ductless glands throughout the body that secretes hormones directly into the bloodstream. These glands include the pituitary, thyroid, thymus, adrenals, pancreas, ovaries or testes, and many others. The function of these glands is to control the internal environment of the entire body.

Hypothalamus

Hypothalamus is the 'brain' behind the endocrine system. It is situated within the brain and is about the size of the tip of our thumb. The hypothalamus in humans accounts for only 1/300 of total brain weight, and is about the size of an almond. It is rich in nerve cells, nerve fibres, and nerve connections and is composed of several sections, called 'nuclei', each of which controls a specific function. This includes temperature regulation, sleep, and emotional behaviour. Hypothalamus also regulates hormones, blood pressure, body temperature, heartbeat, metabolism of fats and carbohydrates, sugar levels in the blood, respiration, and food intake. Through direct attachment to the pituitary gland, the hypothalamus also monitors secretions controlling the water balance and milk production in the female. It also plays a role in regulating complex moods, such as anger, placidity, and fatigue. The hypothalamus is a major centre for the regulation of sexual functions.

The hypothalamus secretes a number of hormones or

factors such as thyrotropin-releasing hormone or factor (TRH/TRF), gonadotropin-releasing hormone (GnRH/GnRF), growth hormone-releasing hormone (GHRH/GHRF), ghrelin, corticotropin-releasing hormone (CRH/CRF), somatostatin, and dopamine. All of these are released into the blood in periodic spurts; they travel immediately to the anterior lobe of the pituitary, where they exert their effects. Two other hypothalamic hormones—antidiuretic hormone (ADH) and oxytocin—travel in neurons to the posterior lobe of the pituitary gland where they are released into the circulation.

The main vehicle used by hypothalamus is the pituitary gland to control other glands. For example, when hypothalamus determines that the level of thyroid hormone in the blood needs to be increased, it releases a hormone to the pituitary gland, instructing it to convey the message to the thyroid gland. The pituitary immediately sends a thyroid-stimulating hormone to the thyroid, instructing it to release more thyroid hormone. When the thyroid gland receives this message, it starts releasing the thyroid hormone, called 'thyroxin'. When this happens, the metabolic rates speed up. In the same fashion, the hypothalamus controls the other endocrine systems, thus controlling the sugar level in the blood, the body temperature, etc.

When we wake up every morning and open our eyes, an immediate and very important electro-chemical chain reaction begins. The eyes open and light streams onto the retina. A cascade of electro-chemical signals flows from the eyes to a nuclear centre within the hypothalamus, the supra chiasmatic nuclei (SCN). SCN not only regulates hormones related to the day/night cycle, but it orchestrates the activities of many other internal clocks. In numerous experiments, it has been shown that when the SCN is not innervated, the human body clocks free run; they set their own time.

Pineal Gland

The pineal gland, also called the pineal body, is a tiny pinecone-shaped organ, located at the back of the brain, just above the brain stem and found behind the hypothalamus in humans (Fig. 3.7). Ancient people called the pineal gland the 'third eye'. It was thought to have mystical powers. This may be why the French philosopher Descartes decided that the pineal gland was the 'seat of the human soul', the location of what we call the mind. Philosophers and spiritual adepts have long contemplated the true function of this mysterious gland. Ancient Greeks believed the pineal gland to be our connection to the realms of thought and was linked to the eye of the Egyptian goddess Ria (Fig. 3.8). This gland is activated by light, and it controls the various biorhythms of the body. It works in harmony with the hypothalamus,

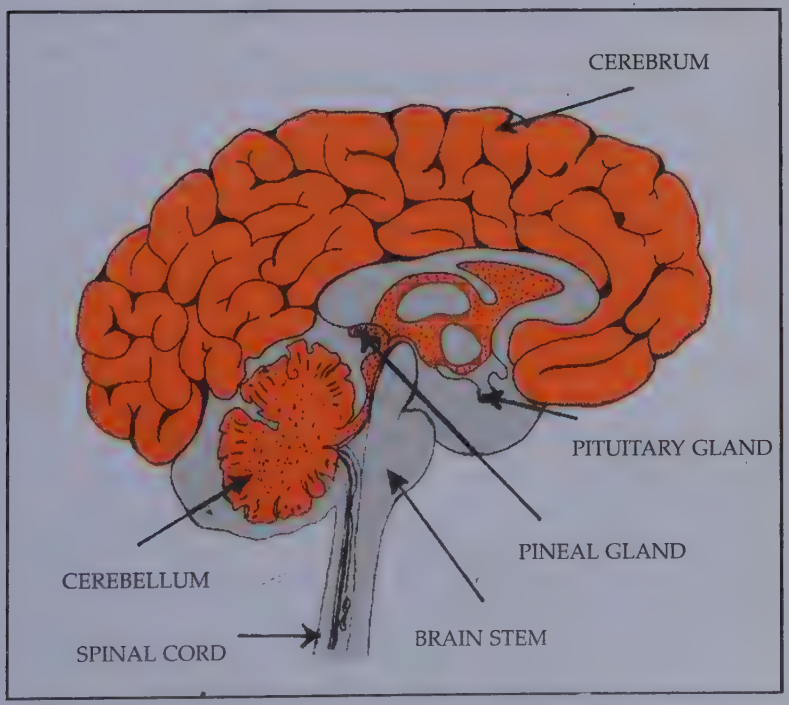

Fig. 3.7: Brain – the pineal gland.

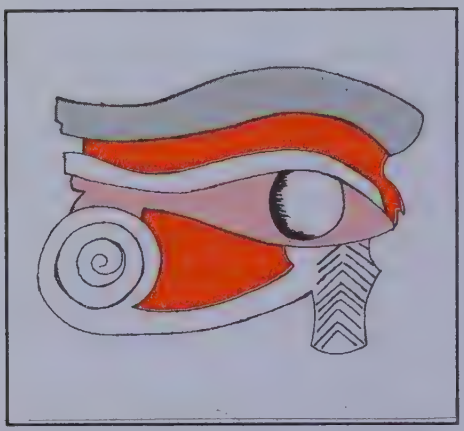

Fig. 3.8: Eye of the Egyptian goddess Ria.

which directs the body's thirst, hunger, sexual desire and the biological clock that determines our ageing process. The pineal does contain a complete map of the visual field of the eyes, and it plays several significant roles in human functioning.

Many scientists believe that pineal gland is the 'ageing clock' for the body. It appears to act as the body's time-keeper by keeping the body in sync with the most constant environmental cue we have: the light-dark cycle. It is the job of the pineal gland to announce to the rest of the body that it is dawn or dusk, time for the body to be awake and alert, or time to prepare for bed and for a rejuvenating sleep. This crucial signal sets complex processes into motion—a cycle that is designed to remain relatively regular and balanced.

In most amphibians, birds, fish and reptiles, the gland is located in the back of the head, just beneath the skin and needs no interaction with the eye to register day/night cycles (this is where the notion of the 'third eye' comes from). It responds directly to light that penetrates the skin. In these animals, the pineal gland is the master clock. In mammals, however, the pineal gland is subordinate to the eye/SCN system. In humans, the pineal gland obtains information about light in the environment by means of nerve pathways originating in the eyes. Pineal gland also receives information indirectly from the SCN.

The pineal gland also appears to act as the body's pacemaker, a kind of 'activities director' for the human life cycle. Scientists believe that the pineal gland, through its

major product, melatonin, triggers the start of puberty and regulates reproductive life. When the pineal gland stops giving out its melatonin-directed signals, we grow old because our bodies are no longer able to operate with efficiency or with internal synchronicity.

Melatonin

The pineal gland secretes a hormone called 'melatonin', which varies with periods of light and darkness in the environment. Light severely curtails the production of melatonin. It appears that the SCN takes the information on day-length from the retina, interprets it, and passes it on to the pineal gland, which secretes the hormone, melatonin, in response to this message. Night time causes melatonin secretion to rise during sleep, while daylight inhibits it. Even when light cues are absent, melatonin is still released in a cyclic manner; yet, if the SCN is destroyed, circadian rhythms disappear entirely.

The role of melatonin in humans is not clearly understood and is currently being investigated, but it is thought to play a role in photoperiodism in seasonally breeding mammals. The SCN is known to have hormone receptors for melatonin. Researchers now use melatonin levels as an accurate marker of circadian rhythms in humans. The circadian rhythm lies at the heart of the state of internal balance and harmony which we know of as health. When it becomes disrupted over a long period of time, there may be serious physical and psychological consequences.

Scientists believe that the pineal gland and melatonin are the body's primary time-keepers—its clock and calendar, imparting information about the time of day, season of the year, and phase of life, to the brain and throughout the body. Melatonin is believed to influence the internal processes so that all of the body's systems work together, in co-ordination. Should this internal structure become disorganised in any way, the body becomes more susceptible to disease.

Melatonin has been linked to the onset of puberty in

humans. Studies have shown that the pineal gland's nightly secretion of melatonin decreases when a boy or a girl reaches puberty. Melatonin regulates daily body rhythms, most notably the day/night cycle (circadian rhythms). Other studies have indicated that melatonin may help regulate menstrual cycles in women and sperm production in men. In addition, researchers have also suggested a connection between melatonin levels and certain mental illnesses.

Since melatonin is produced almost exclusively at night or in a light-free environment, it is nicknamed 'the chemical expression of darkness' by scientists because of its nocturnal habits. Blood levels of melatonin are up to 10 times greater at night than during the day. This high concentration of nocturnal melatonin led scientists to conclude that the production of this hormone signals to the rest of the body that it is time to sleep. Indeed, melatonin supplements have been used for decades to treat sleep-related problems, such as insomnia, sleep apnoea, and jet lag. In the morning, when we perceive that it is light, melatonin secretion ceases, which stimulates the production of other hormones and hence, other body activities to begin. This orderly daily rhythm is of prime importance to our physical condition, intellectual capabilities, and emotional health.

The recent melatonin craze sweeping through the health-conscious community makes claims that the hormone slows the ageing process (a defence against free radicals), prevents jet lag, is implicated in seasonal affective disorder, co-ordinates fertility, and allows for deep restful sleep patterns.

Serotonin

Melatonin affects the production and subsequent action of several other hormones in the body. It works in sync with serotonin—a powerful neurotransmitter from which it is derived. Serotonin is involved in several central physiological processes, including pain perception, temperature and blood-pressure regulation, and several neuropsychological

functions, such as appetite, memory, and mood. Like melatonin, serotonin levels influence a myriad of endocrine activities, including those performed by the hypothalamus and pituitary gland.

Just as melatonin is active at night, serotonin is active during daytime. Although both tend to moderate endocrine functions, serotonin may also have a negative effect on the cardiovascular system if its levels are too high in the bloodstream. Serotonin has been known to cause blood clotting and narrowing of the blood vessels, among other problems. And, unlike melatonin, serotonin levels in the body do not decrease as we age, but instead increase in relation to other hormones and neurotransmitters. Scientists, who specialise in the study of elderly and the aging process, believe that this age-related imbalance between serotonin and melatonin may play as important a role in the aging process as the lack of melatonin itself, particularly in relation to heart disease. Without melatonin to act as a free-radical scavenger during the night, more damage may occur to blood vessels, thus stimulating the release of more serotonin.

Research has shown that in very depressed people, there is a shortage of serotonin, along with dopamine and norepinephrine—three of the neurotransmitters used by the brain. So, the serotonin and melatonin link along with their dependence on the body clock may explain the depression experienced by the people suffering from SAD.

Chronobiology

The study of biological rhythms at different time intervals of 24 hours or one day, one month or a year is known as chronobiology—study of *chronos*—time. It is a science that is concerned with identifying our cycles and internal clocks and seeing how they interact. The study of biological rhythms has now been extended to fast rhythms, such as brain waves, muscle fibre firing, heart rate and respiratory rate. Such natural rhythms, as temperature fluctuations, weather systems, patterns of light and dark are studied to

explore how it affects the life cycle of men and women. And those scientists who study chronobiology are 'chronobiologists'. Chronobiologists also carry out various kinds of experiments to evaluate the relationship between time, rhythms and its subsequent effects on our health and body.

Measurement of Circadian Rhythm

Most chronobiologists study biological rhythms, especially

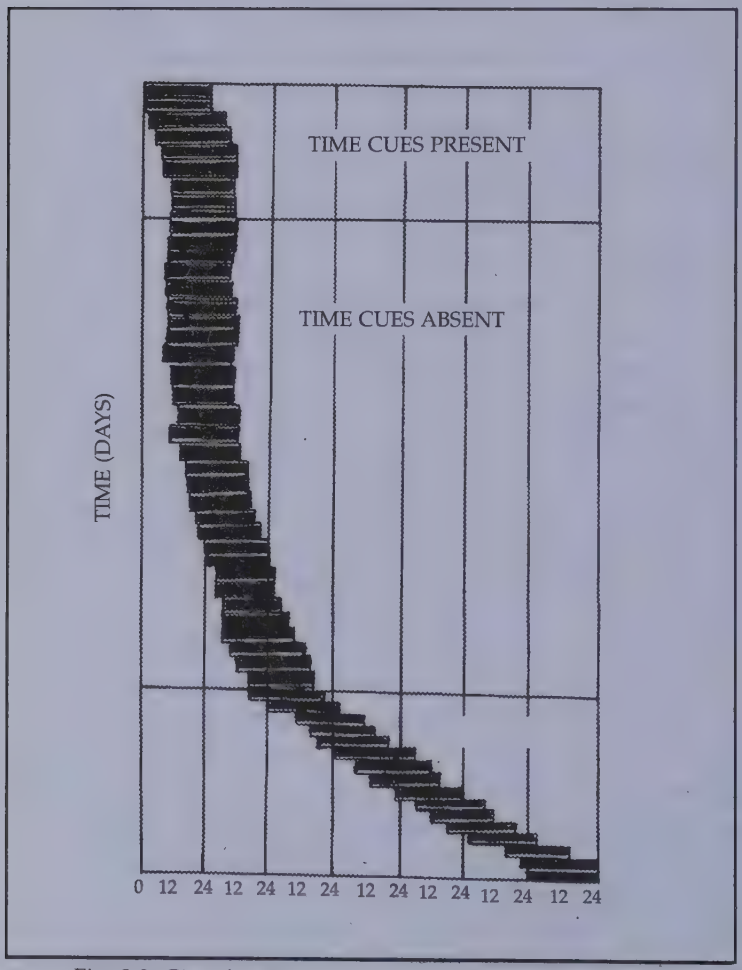

Fig. 3.9: Circadian rhythms can be plotted on an actogram.

the circadian rhythms. They also study the endogenous cycles of behaviour or biological activity that occur within a period of about 24 hours, especially the human sleep-wake cycle, which has a period of one day, or goes through one complete cycle in a day. They study the circadian rhythms by plotting the readings on a graph, called an 'actogram' (Fig. 3.9). An entraining agent (for example, exposure to bright light) can cause a phase shift, whereby the activity is started earlier or later in the day (Fig. 3.10). Like a watch, the circadian clock must be synchronised to local time. For example, animals kept in total darkness will show a free running rhythm that is independent of the local time. A circadian clock is most useful, however, when it is set to local time; the animal must be in sync with its prey, pollinators, and other members of its social group in order to survive. In mammals, the light-dark cycle is a major synchroniser or entraining agent for circadian rhythms.

The evidence that diurnal rhythmicity modulates virtually every aspect of mammalian physiology has forced

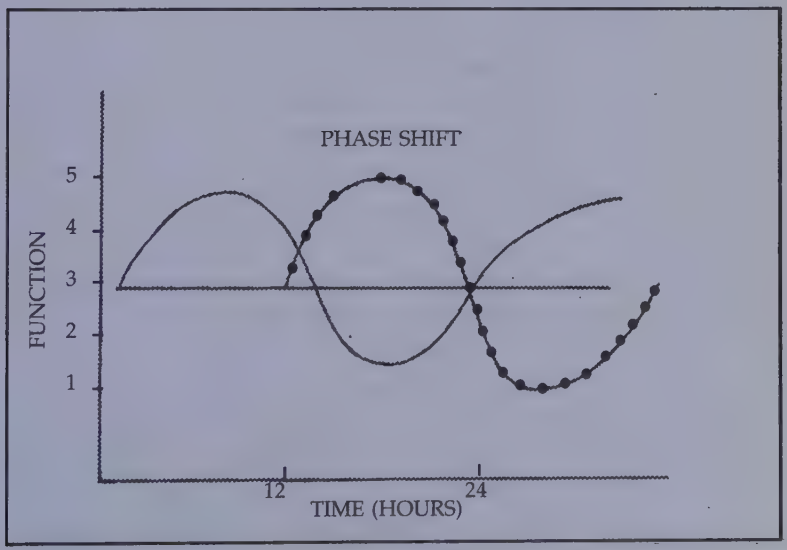

Fig. 3.10: Exposure to entraining agent (bright light) can cause a phase shift (activity is started later in the day).

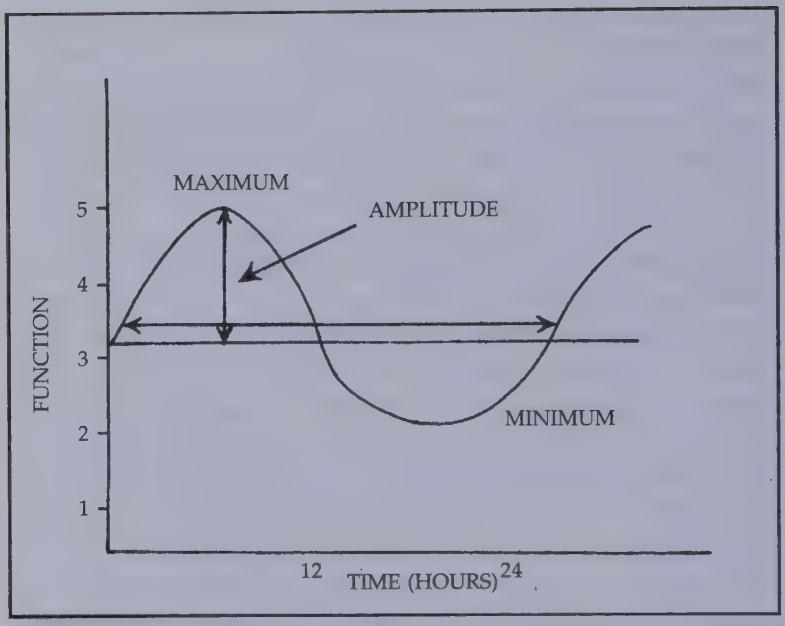

Fig. 3.11: Circadian rhythms of a biological activity within a period of 24 hours.

reconsideration of historical precepts about homeostatic regulation of physiologic parameters. Cycles of peaks of activity and troughs of inactivity occur at various intervals. The cycle time between successive peaks or troughs is called the 'period of the cycle' and the extent of the increase or decrease is called the 'amplitude' (Fig. 3.11). A period can be as short as a microsecond or as long as a year (circa-annual rhythm). In humans, rhythms with a period of about 24 hours (circadian) are of particular interest.

Monitoring Circadian Rhythms in Humans

In order to monitor circadian rhythms in humans, chronobiologists measure melatonin or 6-sulphatoxy-melatonin in blood plasma using sophisticated techniques, such as radioimmunoassay (RIA), and gas-chromatography mass spectrometry (GCMS). Melatonin can also be measured using enzyme-linked immunosorbent assay (ELISA),

fluorimetry and high performance liquid chromatography (HPLC). The measurement of melatonin levels is very important in cases of circadian rhythm disorders, as in old age, advanced and delayed sleep insomnia, sleep problems of blindness, non-24 hour sleep-wake problems, shift work and jet lag, etc. Melatonin measurement also becomes necessary for investigation of normal function of the biological clock, or to precisely define the circadian phase for the purpose of timed treatment and to investigate normal pineal function and pineal dysfunction, for example, pineal tumours, research into certain cases of abnormal puberty and other endocrine abnormalities.

4

FIND YOUR OWN CIRCADIAN RHYTHM

The prelude of the night is commenced in the music of the sunset, in its solemn hymn to the ineffable dark.

—Rabindranath Tagore in *Stray Birds*

We can find our own circadian rhythm related to the sleep-wake cycle by merely observing and studying our own sleep-wake habits. Some of us are late-night sleepers while others take an early night off. Many of us get up late in the morning out of habit, whereas some of us are early birds who love to wake up at the time when the cock crows. Our 'sleep personality' consists of certain natural tendencies that determine to a large degree when and how well we sleep. You can find out if you are 'circadian type', that is, if you are naturally a morning or a night person. You can also discover your 'flex-ability', or how well you can adapt to changes that disrupt your natural rhythms.

You can also find the 'sleep type': whether you are a long or short sleeper by focusing on how much total sleep you need, both during your major sleep period (usually occurring at night) and throughout the day (in the form of naps). Are you a 'napper' or a 'non-napper'? Can you nap easily to make up for sleep loss or to prepare for an expected long day or night? Or must you get all of your sleep in one chunk, no matter how tired you are when trying to stay awake? This aspect of your sleep personality relates as well to your napping capability. Either way, it is important to realise how crucial napping can be.

Your sleep personality also includes how much sleep you need to feel rested and well. If you are a 'long sleeper' nothing less than nine or 10 hours will do, and if you are a 'short sleeper' you may feel great on just four or five hours. You are perfectly healthy either way, but knowing your sleep needs and doing your best to meet them will help you avoid the perils of sleep deprivation.

Scientists used the *Octodon degu*: a frisky laboratory rodent whose name comes from its curious back teeth that resemble the number eight when you look down on them for sleep-wake research. *Degus* run around, eat, and socialise in the daytime. They love their running wheels and spend hours working out. Some *degus* run mainly in the morning, others favour the evening, and the rest show no special preference, according to Susan Labyak and her colleagues at the University of North Carolina, USA. These scientists were the first to document the morning and evening traits in the laboratory in day-active rodents, not specially bred for these characteristics. Of the 49 *degus* that Labyak's group studied, about one in 10 was a distinct morning type, its activity peaking around 7 a.m.; about two in 10 were distinct evening types, most active around 9 p.m. The rest fell somewhere in between. Perhaps just like us!

In essence, we are 'programmed' by our circadian rhythms to sleep at night and to be awake in the daytime. For most people, it is difficult to concentrate and maintain alertness between midnight and 7 a.m. and to sleep during the daylight hours. And it is hard to eat in the night when our digestive system essentially shuts down. However, some people are 'birds of a different feather' as the lark and an owl. One in 10 of us is up-at-dawn, raring-to-go early bird, or lark (Fig 4.1). About two in 10 people may be owls, who enjoy staying up long past midnight. The rest of us, those in the middle, whom we call hummingbirds, may be ready for action both early and late. Some hummingbirds are more larkish, and others, more owlish. The intermediate person can also be called the 'regular robin' that does not go to

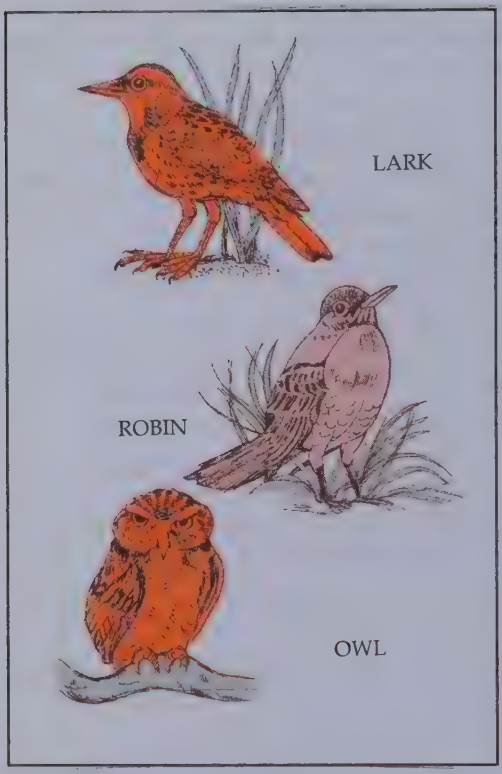

Fig. 4.1: Lark, robin and owl.

either extreme, but can cope with early mornings and late nights, as the need arises. Animal studies suggest that being a morning person or an evening person may be built into our genes, like having red hair or blue eyes. This may explain why those of us who are early-to-bed, early-to-rise types, or late-to-bed, late-to-rise types, find it so hard to change our behaviour.

The 'bird' traits influence many aspects of our daily life, including when we feel most alert and when we sleep best. These traits determine the time when we enjoy meals, exercise, sex, and other activities most. They also affect the time we choose to work, or would, if we could. If you like to linger over your tea or coffee to read the morning paper, you are probably more of a lark. If you were a lark, you probably would not enjoy a job as a night watchman or a bartender. If you were an owl, you would have to struggle to report the morning news. Owls often skip breakfast, and they are always rushing to get to work in the morning. If you like to read a book or surf the Internet at midnight, you are probably an owl. Owls work best as shift workers. If you occasionally get up at dawn to go hiking and jogging and sometimes, stay up long

past your usual bedtime at parties, you are a happy hummingbird.

These 'bird' traits can have individual differences too. A person whose natural pattern of sleep gets him/her up very early in the morning and makes it difficult for him/her to sleep, in spite of being forced to stay up past the normal bedtime, is a 'rigid lark'. You are a 'regular robin' if you usually to go to bed between 10 p.m. and midnight, generally wake up between 6 a.m. and 8 a.m., and can manage to function fairly well on either end of the spectrum, if circumstances so warrant it. Regular robins have fairly flexible sleep patterns. They generally go to bed before midnight (but not before 10 p.m.), usually wake up after 6 a.m. (but not after, say, 8 a.m.), and adapt fairly easily to changes in this schedule. However, if you are a 'flexible owl', you really do crave for the night and function best after dinner, but can manage to adjust your regular schedule to keep up with the average nine-to-five worlds if necessary. A flexible owl is a good old-fashioned 'night person' who prefers staying up until after midnight (and maybe even until 1 or 2 a.m.), but who can adapt to a nine-to-five routine if need be.

We humans are not programmed to work at night, although some of us think that we are night people. We function best in the daytime. The fact that we cannot see in the dark suffices. Even if we insist on shifting our schedules to work at night, Mother Nature is not fooled. Night is still the down time on the body clock. Lark-owl traits may play a bigger role in job choice than most of us suspect. Casualty doctors or emergency-room doctors, for example, spend more time working at night throughout their lives than doctors in other specialties. It is no mere coincidence that these doctors prove to be owls more often than larks. Artist Edward Hopper often portrayed these extremes. In the painting *Cape Cod Morning*, a woman already dressed for the day gazes out of her living-room window at trees bathed in dawn light while in *Nighthawks*, a man and a woman in

evening clothes sip coffee in an all-night dinner.

It is true that most of us view our schedules as a compromise between what we have to do, and what we would like to do. Most people say they would like to sleep later, for example, teenagers or college students who seldom go to bed before 12 midnight and get up late in the morning, almost certainly will turn off the lights earlier after they graduate. They are likely to enter the daytime workforce and tend to become even more larkish after they become parents. They might complain, but most will manage. By the time they are in their sixties and over, most will be comfortable going to sleep and getting up earlier than they did when younger. All of us might feel and function better, though, if only we could synchronise more of our required activities with our natural rhythms throughout our lives.

Genes Governing Owls and Larks

Being a lark or an owl is not a choice, but it is built into our genes, and it helps to understand our own proclivity. A gene specifically may govern owlish behaviour in humans. Daniel Katzenberg and his colleagues at Stanford University, USA, assessed 'morningness'/'eveningness' traits in 410 randomly sampled adults with a questionnaire. They also drew blood samples from the respondents, and examined the make-up of a gene called 'clock' which is known to exert influence over biological rhythms. Comparing results from the two tests, they estimated that the owls remained 10 to 24 minutes behind larks in their preferred times for various activities and for sleep, which is indeed a significant difference. Moreover, a particular pattern consistently appeared in part of the *clock* gene in owls, but not in larks.

The 'morning larks', sleep before dinner, then awake before dawn, while some people sleep at odd, unpredictable intervals. In severe cases, sleep-phase disorders interfere with work and social activities, and may cause other problems including sleep-deprivation and depression. Some sleep problems are in the genes, such as the familial

advanced sleep-phase syndrome (FASPS) disorder, which causes patients to fall asleep very early in the evening, and then wake up in the wee hours of the morning. In due time, genes might surface that make people sleep longer in the morning. The proteins encoded by these genes, scientists hope, could serve as drug targets to help people with transient sleeping problems that are the result of, say, jet lag or working in night shifts.

Genetic studies may prove a two-edged sword. They potentially could help workers decide which jobs suit them best. But they could also be used to discriminate against workers whose genetic traits do not correspond to an employer's criteria. That would be unfortunate, because lark/owl tendencies do not really rule most people's lives. High motivation for all but extreme larks and owls probably has a much bigger impact on job success.

When people choose to sleep, how well they control bedroom darkness, and workplace lighting also, affect circadian rhythms. In essence, we are 'programmed' by our circadian rhythms to sleep at night and to be awake in the daytime. You can find out what type of 'sleep personality' you are by using the lark and owl test.

Lark or Owl Test

Are you a morning person—an early riser (lark) or an evening person—a late riser (owl)? One simple question is, what is your favourite meal? Extreme larks love breakfast, but night owls typically say their favourite meal is dinner. 'Morningness' and 'eveningness' are the two terms used to describe a person's individual circadian profile. 'Morningness' refers to those individuals who tend to be early risers. Morning people usually prefer to rise between 5 a.m. and 7 a.m., and retire between 9 p.m. and 11 p.m. Evening people tend to prefer both a later wake-up (9 a.m. to 11 a.m.) and a later bedtime (11 p.m. to 3 a.m.) Morning people also tend to be more rigid in their circadian rhythms, while evening people find adjustment to new schedules somewhat easier.

However, a majority of people fall somewhere between these two types, showing strong preferences for neither morning nor evening timings.

How Larks and Owls Differ

Characteristics	*Larks*	*Owls*
Most alert (self-report)	Around noon.	Around 6 p.m.
Most productive (self-report)	Late morning.	Late morning, and late evening.
Most active	Around 2:30 p.m.	Around 5:30 p.m.
Best mood	Between 9 a.m. and 4 p.m.	Steady rise from about 8 a.m. to 10 p.m.
Temperature highest	Around 3:30 p.m.	Around 8 p.m.
Age	Most persons over age 60.	Most college students and those 20 plus.
Bedtime	Go to bed two hours earlier than owls; fall asleep faster.	More variable bedtimes; stay up later on week-ends and holidays.
Wake time	Awaken at desired time.	Awaken about same time as larks on workdays; one to two hours later on days off.
Use of alarm clock	Don't need it.	Need multiple alarms.
Temperature lowest	Around 3:30 a.m.	Around 6 a.m.
Quality of sleep	Lifelong: sleep more soundly, wake up more refreshed; usually three to four hours after minimum temperature; daily low point on body clock.	Lifelong: get less sleep; wake up sleepier, usually two-and-a-half hours after minimum temperature.
Nap	Rarely.	Take more and longer naps; fall asleep more easily in daytime.
Mid-sleep time	Around 3:30 a.m.	Around 6 a.m.
Favourite exercise time	Morning.	Evening.

Characteristics	*Larks*	*Owls*
Peak heart rate	Around 11 a.m.	Around 6 p.m.
Lowest heart rate	Around 3 a.m.	Around 7 a.m.
Mood	Mood declines slightly over day.	Mood rises substantially over day.
Morning behaviour	Chirpy.	Bearish.
Evening behaviour	Out of steam.	Full of energy.
Meal times	Eat breakfast, one to two hours earlier than owls.	Often skip breakfast; eat other meals at same time as larks on work-days; 90 minutes later on days off.
Favourite meal	Breakfast.	Dinner.
Daily caffeine use	Cups.	Pots.
Personality	More introverted? (still debated).	More extroverted? (still debated).
Shift work adaptability	Work best on day shifts.	Work best on evening shifts; tolerate night and rotating shift; work better.
Travel	More jet lag.	Adapt faster to time-zone changes, particularly going West.
Partner's report (if well-matched)	Likes to get an early start.	Last to go home.
Partner's complaint (if mismatched)	He/she stays up too late.	She/he won't let me sleep late on weekends.
Peak melatonin secretion	About 3:30 a.m.	About 5:30 a.m.

Source: *The Body Clock Guide to Better Health* by Michael Smolensky and Lynne Lamberg.

In general about one in 10 persons is an extreme lark, or a morning person, and about two in 10 are owls, who enjoy staying up long past midnight. The rest of us are somewhere in the middle. Everyone needs to figure out his or her own best time, and to try to adapt their life to their own natural rhythm as far as possible. Luckily for night owls, there are plenty of jobs available in today's world because

of the Internet and the global economy. The biggest problem for night owls is trying to conform to a nine-to-five world. It really helps if they can find a way to adapt their work and daily life to their natural tendencies.

Left-handed people may want to learn to write with their right hand and vice versa. An overweight person may want to turn into a slim person. In the same way, most larks and owls may want to change their habits in spite of being able to manage most schedules as their jobs, families, or social lives demand. Larks may want to live more like owls and owls may want to live like larks. You can take advantage of recent research on the biological clock to ease this task. Changing according to the biological clock can help you adapt more comfortably to situational demands. Some will feel more discord than others when they try to follow clocks at variance with their natural proclivities.

Suggestions offered by Michael Smolensky and Lynne Lamberg, the authors of *The Body Clock Guide to Better Health* are as follows:

If you are a lark:

- Spend time outside in the afternoon or early evening. This tactic should help you stay up later, and may help you sleep later in the morning, too. It is especially helpful to older persons, who often go to bed as early as 8 p.m. and find themselves awake, with nothing to do, at 3 a.m.
- Increase evening activity. A walk or light stretching will promote alertness. Socialising is more energising than reading or watching TV.
- Sleep with blinds or curtains closed. Consider purchasing 'black-out' drapes. Darkness tells your brain it is night-time, the right time for sleep.
- Leave a dim night-light on in hallways or bathroom in case you have to get up at night.
- See a doctor if you can't stay awake in the evening until a reasonable 'social' bedtime, at least 9 p.m., and if you always awaken around 3 a.m. or 4 a.m. and are unable

to return to sleep. If this condition developed over the years, particularly late in life, you may have a condition called the Advanced Sleep Phase Syndrome (ASPS).

If you are an owl:

- Sleep with blinds or curtains open, and let daylight awaken you naturally. It is a gentle process and much easier to take than the annoying bleat of an alarm clock. Set the alarm anyway. Hey, set two alarms, for safety's sake.
- Walk outside as soon as possible after waking up. Exposure to daylight in the morning can make you more alert earlier in the day. One sleep specialist tells his patients, "Take your dental floss and step outside." Since owls often leave things to the last minute, it may be hard to get up in time to have breakfast outdoors or to take a twenty-minute walk. Trick yourself by setting the clock a few minutes fast. Close your eyes when you do it, so you won't know if the clock is five minutes or fifteen minutes fast. When rushing in the morning, you will have a small safety net, but not enough to start making allowances for it. If you cannot go outside immediately, have your morning coffee by the sunniest window in your home, or use a lighting device that provides artificial light of daylight intensity.
- Get up at the same time every day, including weekends and holidays. This tactic will anchor your biological clock at the desired time. If you go to sleep late one night, do not sleep the next morning. Compensate for missed sleep with a 20-minute mid-afternoon nap, unless you find naps leave you foggy. In that case, go to bed 15 minutes earlier the next night.
- Do as much as you can the night before. Select the next day's clothes, put cereal boxes on the breakfast table, and prepare school lunches. A morning routine helps owls function smoothly without having to think about what they are doing. If you are sleepy, rote behaviour

fills time until you are more alert.

- Keep evenings quiet. Do not exercise, start new projects, or look at TV 'for just a few minutes' late at night. Reading, listening to music, and similar activities are good preludes to sleep. Have a regular bedtime snack, such as milk or fruit. This ritual also helps programme your body for bed.
- Use dim lights at night in the bathroom to avoid giving you a middle-of-the-night wake-up call the next night.
- See a doctor if you cannot fall asleep before 3 a.m. or 4 a.m., and if you could sleep until noon or later if permitted to do so. You may have a condition called the Delayed Sleep Phase Syndrome (DSPS).

Couples who are considering marriage need to examine their partners' and their own tendencies to be a morning person or a night person in the same way they consider questions about religion and jobs. Couples where both persons are matched, either owls or both larks, generally rate their marriages as more satisfactory than those who are not well matched. However, couples that are not well matched do also work at it and can also have a great relationship. Civility is the key to getting along despite individual differences.

The problems arise mostly if you are an extreme lark or an extreme owl. These individuals may find it somewhat difficult, if not impossible, to function in some situations. Extreme larks or owls are not sick, lazy or are not lacking in motivation. Their 'bird' personality makes them so. However, in our 24-hour world, there are plenty of spots where most larks, owls, robins and hummingbirds, all can find a secure perch.

5

SLEEP, LIGHT AND SEASONAL CHANGES

Whoever wishes to pursue the science of medicine in a direct manner, must first investigate the seasons of the year and what occurs in them. Yet generations of physicians have paid little heed.

—Hippocrates, Greek physician

Circadian rhythms are the cyclical variations that mark the ebb and flow of daily life. These include waking and sleeping, the rise and fall of blood pressure and heart rate, and other factors such as gastrointestinal, renal, and immune system activity. Normally the internal body clock aligns its timing to the external environment through exposure to sunlight. If the clock is stimulated by light before it expects the Sun to have risen, it will reset itself to an earlier time. If stimulated by light after the time it expects the Sun to have set, the body clock will reset itself to a later time. The most important phenomenon that circadian rhythms show is that of sleep and wakefulness.

Sleep

Sleep takes up about a third of our lives, and if we are not sleeping properly, this seems to cause a big impact on our daily lives and our overall quality of life. Sleep problems in people with pituitary disorders are fairly common, and range from insomnia (difficulty in initiating or maintaining sleep) to hypersomnia, or excessive sleepiness during the day. To be healthy, three conditions need to be met ceremoniously.

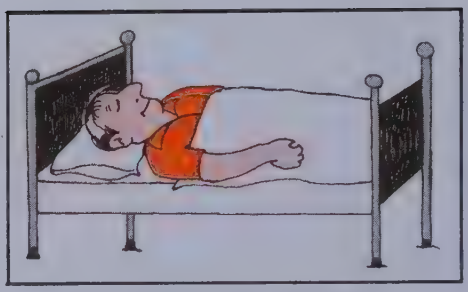

Fig. 5.1: Good night's sleep.

Firstly, have a good night's sleep (Fig. 5.1) when it is bedtime on your 'body clock'; secondly sleep at an appropriate time after about 16 hours of remaining awake after your last sleep and lastly, sleep when your level of alertness, or arousal, is lowered and awaken when the level of alertness returns and you feel fresh.

We have seen that in humans the circadian pacemaker, SCN, helps the body keep time and it controls a number of body functions and interacts with the mechanisms controlling sleep. For most people, studies show that the pressure to sleep builds up throughout the day and peaks around 9 p.m. to 10 p.m. At this time, the body's temperature starts to drop and lowers about one degree during sleep. As it starts to rise, around 4 a.m., the likelihood of waking increases. In addition, the pineal gland produces and secretes melatonin at high levels during the night. A number of factors can affect melatonin secretion, especially many common medications and light. For example, a lamp turned off at bedtime can affect the stimulation of the pineal gland, and sunrise triggers the chemical process that enables a person to begin waking up.

Sleep-Wake Cycle

To sleep or not to sleep! A good night's sleep is one of the greatest restoratives known to mankind. Yet what happens when work schedules or international travel reverses typical circadian sleep-wake patterns, or during sustained operations when day and night merge? The subject of sleep has intrigued people for centuries. Centuries ago sleep was confused with death. During the time of Roman Emperors, death and sleep were inseparable for the Germanic tribes.

"O sleep, thou ape of death, lies dull upon her! And be her sense but as a monument," wrote William Shakespeare, the noted playwright, in his drama *Romeo and Juliet*, and made the heroine Juliet consume a powerful potion that would put her to sleep at the end of the play. Not only did the death-like sleep fool her family but also Romeo, her lover, who then killed himself out of desperation.

The scientific study of sleep is equally intriguing and offers some valuable insights into managing a 24-hour lifestyle. Sleep is not a simple shutdown of the brain. Instead, it comprises several distinct stages, each characterised by different brain-wave activities that recur repeatedly throughout the night. These recurring patterns form what is often call 'sleep architecture'. The need to sleep is irresistible. Sleep can be so peaceful that people look forward to it. Rightly said Don Quixote in *Cervantes*, "Blessings on him that first invented sleep." On an average, each one of us sleeps for about seven to eight hours a night, which means we spend almost one-third of our lives sleeping. But then, there are some individuals who need very little sleep. Napoleon Bonaparte slept not more than four hours while Albert Einstein needed 10 hours of sleep during the night. Animals too exhibit sleep behaviour. Pigeons, dolphins, rats, moths and flies: they all need rest and sleep. No one can live without sleep!

Researchers had long known about four phases of sleep, each having its own characteristics. Modern sleep research reached an interesting high in the1940s, when American Nathaniel Kleitman in Chicago, USA observed the slow and sweeping eye movements when people fell asleep. Since he was too busy with other work, he handed over the project to a graduate student Eugene Aserinsky, who recorded the electrical activity of the muscles in the eye socket. The co-ordinated contractions of the eye muscles moved the eye up and down, back and forth. The needle of the electro-oculogram (EOG), moved violently on the paper, long after the individual had fallen asleep. The needle matched the

eye movements and the pattern was recorded on the paper. When the sleeping individuals were suddenly awakened around this time, they reported that they had been dreaming. This newly discovered stage of slumber was given the name, 'rapid eye movement', or REM sleep. And the rest of the four sleep phases were termed as non-REM sleep.

Sleep Cycles

Sleep is composed of several repetitive cycles of about 90 minutes in length. It is composed of two types of sleep: REM and non-REM sleep. In REM sleep the individual undergoes a relatively brief period of vivid, erratic dreams. To unravel the activities of the brain in a sleeping person, electrodes are attached to the skull and the electroencephalographic or EEG pattern is recorded on the paper. Wires are pressed onto the skin of the jaw and onto the flesh around the eyes to measure the fine movements of the muscles. All these are attached to a polygraph: a device that records the electrical signals on paper. When EEG monitors the brain, the brain activity is similar to the EEG of a person in a state of wakefulness, and yet it is more difficult to awaken sleepers in REM sleep, indicating that REM sleep is still a type of deep sleep.

Physiologically the body picks up the pace as well: there is an increase in heart rate, eye movement, and respiration. In non-REM sleep, there are four stages progressing into a deep sleep or slow-wave sleep. In this slow-wave sleep the body physiologically slows down and the EEG takes on a new amplitude and appearance. So, within the 90-minute sleep cycle, the body undergoes at first a cycle of non-REM sleep, followed by a shorter period of REM sleep. These cycles then continue throughout the night with the REM period getting slightly longer as the evening progresses.

Journey through Sleep

As we journey into slumber, our body temperature and blood pressure drop. The rate of breathing and the heart

rate slows down. Initially the needles recording the EEG vibrate rapidly back and forth in short strokes. These are the alpha rhythms, which show that the brain is relaxed but alert. The movements of the eye muscles and a firm jaw confirm this fact. A little later we sink into the netherworld; the alertness vanishes. The rapid scribbling of the needle turns into a rapid irregular scrawl. The EEG alpha rhythms change suddenly, the body muscles relax, eyes roll slowly back and forth and we enter into stage I of sleep, which lasts only from one to three minutes.

Stage I is followed by the second stage of sleep during which the EEG pattern shows slightly larger vibrations. These are overlapped with occasional bursts of activity waves, known as 'sleep spindles'. Sometimes the pattern is interrupted by large sweeping waves called the 'K-complexes'. At this time the muscles of the body become less tense than they were when we were awake and the eyes remain motionless. The stage II lasts for about 10 to 15 minutes and then slowly gives way to stage III.

The stage III EEG rhythms of the brain are called the 'delta waves'. These present themselves as large and slow waves. Our body enters into deep sleep. It is during this stage that the pituitary gland situated at the base of the brain releases large bursts of growth hormone, a hormone that co-ordinates the body's mechanism. This is also the time and place where during puberty, most of the sex hormones, testosterone and luteinising hormone (LH)—a substance required in the female for her monthly release of eggs, are secreted into the blood. We stay in this stage merely for five to 15 minutes.

From this stage we sink into stage IV, the deepest sleep stage for about 30 minutes when our muscles and eyes remain relatively still. From this stage, we travel back into stage III, remain there for about 10 minutes and move up to stage II for another 10 minutes. Our mind rides as per these sleep waves for almost about an hour and 20 minutes. Suddenly, the visions turn bizarre and the scenes turn chaotic

and colourful. We begin to dream and fall into the REM sleep.

The polygraph needles turn wild; they move rapidly. The EEG pattern resembles the scribbling of stage I sleep, characteristic of mental alertness. The muscles of the body turn limp, however, the breathing and the pulse rate quicken and blood pressure rises. In man the penis becomes erect, though the man is not necessarily dreaming about a sexual episode. Even infants have erections during this period. The REM sleep too alternates between two stages, called REM-M and REM-Q, named after the movements of our eyes—moving (M) and quiescent (Q). In REM-M, our eyes follow the activity on the dream stage. We do not chase these images, but our eyes track them and we see images as if we were watching a drama scene sitting in the audience. The dream ends and we switch into REM-Q sleep. The eyes during this stage remain still but the body tends to move about. If someone wakes us up at this time, he or she would remember the dream on awakening. If left undisturbed, we would dive back into REM-M, again.

It is 90 minutes since we have fallen asleep and it is time for the new cycle to begin. From our dreams we travel back up to stage II and stay there for a little longer than before, say, for about 20 to 30 minutes. Then we go back to stage III and then to stage IV for about 10 minutes. From here, we go back to stage III for five minutes and to stage II for two minutes, only to nosedive back into the sea of dreams—the REM sleep for almost 15 minutes. Slowly the stages of deep sleep III and IV are beginning to disappear and by the end of the third 90-minute cycle, only REM and stage II sleep remain for the rest of the time, until we wake up in the morning.

The EEG patterns of infants surprisingly look similar to the patterns when they are awake. The elderly tend to sleep more during the day than at night and their sleep is erratic as they wake up repeatedly. They tend to spend less time in deep sleep than younger adults do. Yet, the amount

of REM sleep in both young and elderly remains relatively constant.

Natural Alarm Clock

Our inability to wake up in today's darkened bedroom created the need for an alarm clock. Perhaps the person responsible for inventing this device, which in its time fulfilled a genuine need, recognised the value of roosters crowing at daybreak, and attempted to emulate the sound. 'The blaring, buzzing, dreaded alarm clock!'(Fig. 5.2). The rude awakenings in modern life certainly contribute to the daily stress we face. More importantly, this type of awakening may fail to support our delicate and complex body systems. Perhaps the worst side effect of an alarm clock is that in some people, it can stimulate the 'fight-or-flight' human defence mechanism. Since human beings are biologically programmed to wake up to sunlight, audio-awakening devices seem diametrically opposed to our biological needs.

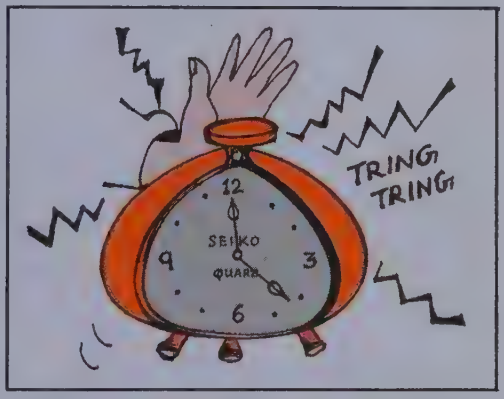

Fig. 5.2: Wake up call from an alarm clock.

Audio devices of any kind trigger a response of sudden wakefulness; that is, a quick and disturbing rush of adrenalin. Our body reacts by sending the appropriate fight-or-flight chemicals into our bloodstream. This prepares our body mechanisms to fight or run away. There is no need for such chemicals to be surging in our bloodstream at this time of day, as there's nothing to fight, nothing from which to run. Nevertheless, we awaken each morning physically and emotionally armed for battle.

We must not forget that we humans do have our own natural alarm clocks, which can be set subconsciously just by anticipating the time at which we want to wake up. Research conducted by scientists at the University of Lubeck in Germany has found that people release hormones before waking, which help them to anticipate the 'stress' of getting up at different hours. Their work has also revealed the importance of the power of thought when it comes to controlling our sleep patterns. A surge of hormones—adrenocorticotrophic hormone (ACTH) and cortisol, is our body's way of saying 'wake up!' But this happens only when we are expecting to wake up. Previous research has shown that people's bodies have their own rhythms, which can help them wake up at regular times each day. This is the first real evidence of an internal mechanism, which quickly adapts the sleep-wake rhythm to environmental challenges. Scientists believe that greater understanding of sleep could allow researchers to develop ways of improving the lot of shift workers whose sleep patterns are constantly being disrupted.

Sleep Deprivation

Sleep deprivation makes one feel awful and listless. In earlier times, the ancient Romans used sleep deprivation as a form of torture for their prisoners. During the Middle Ages too, insomnia torture was used to extract confessions from the culprits. According to the *Guinness Book of World Records*, the longest recorded period for which a person has voluntarily gone without sleep is 453 hours and 40 minutes. Robert McDonald of California, USA lay awake for almost 19 days in a rocking-chair. Victims of the very rare condition called 'chronic colestites' (total insomnia) have been known to go without definable sleep for many years. However, for a normal individual, it becomes difficult to repel sleep.

Sleep deprivation is sometimes easily masked or hidden by activity that we engage in, or our environment. Most dramatically affected by inadequate sleep is the inability to

pay attention. Sustained attention, such as the kind required when one drives a motor vehicle, particularly for long distances, is eroded early and dramatically by sleep loss. Our thought processes also slow down when we are sleep-deprived. We still can think, and think accurately, depending on the magnitude of the sleep deprivation, but we do not think as quickly as when we are fully alert. In other words, we slow down to try to maintain accuracy.

Physical reaction becomes too slow with sleep loss, again making driving and sleepiness a dangerous combination. We can have difficulty remembering things that we may have just seen, or heard. In addition, sleepy people, or people with sleep loss, struggle to stay awake whenever the environment is not stimulating, such as a boring meeting. Emotionally, people can become apathetic and if challenged to perform, they may become angry, or resistant to co-operation. Physically, sleep loss, especially chronic sleep loss, can affect our body's physiological response to food. There is also some evidence that our ability to mount an effective immune response may be changed by sleep loss and the stress of performing and working in the face of a sleep debt.

It is true that sleep may have evolved for restoration of body parts. Less energy is consumed during sleep as compared to that when awake; body temperature becomes lower during sleep and there is no production of protein during sleep. However, sleep does not mean a system shutdown. It is an active process, especially at the brain level, because at the time when the person sleeps, the brain keeps busy. Melatonin is the one that makes one sleepy. Children produce more of it at night; therefore, they sleep for a longer time than adults.

To determine if you are sleeping enough, you need to evaluate how alert you are during daytime, or during your wake period, especially if you are a night-shift worker. If you are sleepy frequently, or intensely, for even brief periods during the daytime, then it may be likely that you are not getting adequate amounts of quality sleep, even if you are

spending an adequate amount of time in bed for sleep. Some people with sleep disorders spend time in bed, but do not sleep restfully. Others, who do not have sleep disorders, simply do not spend enough time in bed sleeping. Either way, you can develop a significant sleep debt and become impaired by sleepiness during daytime, or at night when you're attempting to work or play.

Although many people believe that they can get too much sleep, this really may not be possible physiologically. The brain, which is the organ that needs sleep and ensures that the body gets sleep, will wake up when it has had enough sleep. The awakening will then be spontaneous, without the need for an alarm clock or other waking signal. Some sleep disorders will awaken the sleeper spontaneously, not because the brain has had enough sleep, but because there is a problem in the body or the brain that makes it unable to sustain sleep. You really cannot oversleep beyond your basic sleep need. At least not for more than a day or two.

The pattern of under-sleeping during the week and oversleeping during the weekend is common, and typically, practised by youngsters. Studies show that teenagers need, on an average, nine hours and 20 minutes of sleep at night. Few of them get this much, because most schools and colleges start too early. An average teenager feels most comfortable going to sleep after 11 p.m. As a result, teenagers do not get the sleep they need, to be fully alert in class. Some studies show that teenagers who get more sleep get better grades and are less apt to use drugs.

Healthy young adults can recover some of the functions that they lose by under-sleeping during the week, but it appears as though it cannot be done within one night of oversleeping. Recent evidence suggests that two, three or possibly even four or more nights of oversleeping may be required to reduce the sleep debt to zero and recover the waking alertness degraded by that debt. As we age, it becomes more difficult to oversleep and recover the sleep debt for reasons having to do with age-related changes in

our sleep drive and the biological timing clock that regulates the drive. In other words, as we age, even when we attempt to sleep longer on the weekend, we are often awakened internally by our biological clock.

As every parent knows, infants are seldom on the same sleep-wake cycle as the rest of the family. In human infants, the sleep-wake cycle is initially nearly random. At about six weeks of age, the circadian rhythms begin; by about 16 weeks, the baby is entrained.

What do the following have in common? Grandmother goes to sleep at 7 p.m. and wakes up at 3 a.m.; a newborn baby keeps its parents awake, never seeming to sleep on schedule; certain types of drugs must be taken at a specific time of day or they can be deadly; and travellers feel disoriented and fatigued after a cross-country flight. All of these problems result from disruptions of the biological clock.

Early sleep-wake experimenters eliminated all external cues, such as light and sound, to understand the human sleep-wake cycle. Since these early studies, many researchers have gone on to study the human sleep-wake cycle. One of the most intriguing happenings, perhaps, was that of scientist Michael Siffre who spent six months alone in a cave. To comprehend the free-running sleep-wake cycle, Jurgen Aschoff in Germany, built an isolation facility, known as *tier bunker*. Starting in 1961, the test subjects stayed in the bunker for three or four weeks and revealed a sleep-wake cycle of about 25 hours. They were allowed to turn the light on and off at will, but no external cues could reach them. Under these controlled conditions, all subjects displayed clear circadian rhythms, and experimental changes in room temperature seemed to have no effect on their cycle.

Anyone who has had even an occasional bout of insomnia knows that it can affect the next day's performance. The elderly, those over 65, seem to be particularly prone to sleep rhythm disorders. Many elderly individuals complain of chronic sleeping problems, and as a result, they need to take sleeping pills. Their problems include: less total daily

sleep; more frequent and longer awakenings during the night; a phase shift causing them to go to bed earlier and get up earlier (advanced sleep phase syndrome); and more and longer daytime naps.

Sleep Disorders

An individual's circadian system seems to be affected by genes. Age-related changes in the circadian system also appear to influence the natural rhythm and ability to respond to time cues. These factors can lead to a conflict between the body's sleep cues and the demands of society. Scientists are just beginning to understand how the circadian system works and what can be done to improve our ability to cope with these problems. Sleep phase disorders occur when a

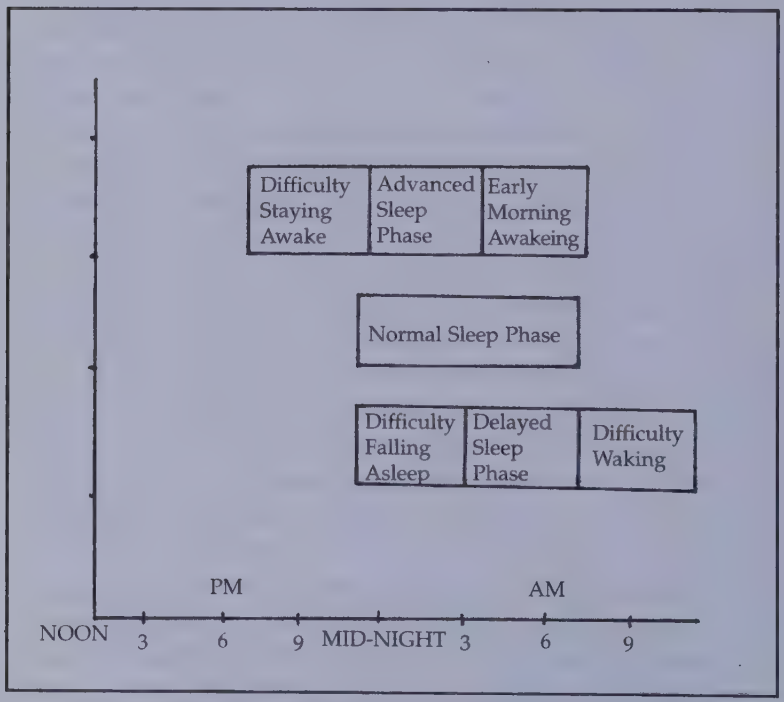

Fig. 5.3: A schematic representation of a normal sleep-waking schedule and of an individual with delayed sleep phase syndrome (DSPS) and an advanced sleep phase syndrome (ASPS).

person's internal biological clock is normally delayed or advanced from the external environment (Fig. 5.3). Chronic sleep deprivation predisposes us to a pre-diabetic condition, and, therefore, to an elevated risk of obesity.

Sleep Apnoea

Sleep apnoea is a disease in which the sleeper stops breathing frequently throughout sleep, thereby disrupting the brain's sleep stages and producing non-restorative sleep and day-time impairments. Many people suffer from obstructive sleep apnoea caused by blocking of the airway by either a portion of the nose or throat during sleep. Snoring is different from sleep apnoea as it occurs when some part of the throat flutters when we inhale or exhale during sleep. Most people who have obstructive sleep apnoea also snore, but not everybody who snores has sleep apnoea. Other than the loud noise, which may disturb bed partners, snoring is not believed to cause any health problems. Obesity is generally sleep-associated apnoea. Millions of people have sleep apnoea, but the disorder is treatable if properly diagnosed and treated. There are several intra-oral mechanical devices available that may be effective in reducing sleep apnoea. These devices work by moving either the tongue or the lower jaw forward.

Delayed Sleep Phase Syndrome (DSPS)

Do you go to bed early, do not get sleep or wake up too late? Some people find that they are not able to fall asleep until 2 or 3 a.m., and that they then have trouble waking up in time for work or school. This problem can interfere with both daily performance at work and school. Few lifestyles allow for this kind of sleep/wake schedule and psychological stress is often a result. These are people with DSPS who find it difficult to fall asleep until the early morning hours, and difficult to wake up until the late morning, or even afternoon. This problem is more common in younger people.

The treatment for DSPS is chronotherapy or time therapy (discussed in later chapters), which involves going

to sleep three hours later every day until you reach your desired bedtime.

Day 1: sleep 4 a.m. to noon
Day 2: sleep 7 a.m. to 3 p.m.
Day 3: sleep 10 a.m. to 6 p.m.
Day 4: sleep 1 p.m. to 9 p.m.
Day 5: sleep 4 p.m. to midnight
Day 6: sleep 7 p.m. to 3 a.m.
Day 7 to 13: sleep 10 p.m. to 6 a.m.
Day 14 and thereafter: sleep 11 p.m. to 7 a.m.

This is difficult, although for people with DSPS, it is often much easier than just trying to wake up at 7 a.m. from the first day.

Advanced Sleep Phase Syndrome (ASPS)

Do you wake up too early and go to bed too early? For most, sleepiness begins in the early afternoon and results in an early bedtime. This is ASPS when the internal body clock is set much earlier than the external environment. People with an advanced clock tend to become tired in the late afternoon or early evening. They then find themselves waking early in the morning. When morning comes, sufferers of ASPS often wake up too early and then are not able to go back to sleep. ASPS is more common among older adults and has only recently been recognised as a significant medical problem.

Weak Circadian Cycle

Some people seem to have a non-existent or weakened circadian cycle. They become sleepy after being awake only for a few hours and then nap for a few hours. These napping sessions occur randomly throughout the day. The constant napping often ends up substituting for a full night's sleep. Clock failure is a rare condition in otherwise normal individuals, but it has been recognised for several years as one manifestation of a neurologic disease, involving the hypothalamus. These individuals may have episodes of

sleep and wakefulness scattered throughout the 24-hour period in a random fashion, analogous to that seen in animals with lesions of their SCN. In each such case, a tumour or other destructive neurological lesion has been identified as the cause.

Insomnia

One of the most common sleep disorders that people suffer from is insomnia, which refers to not being able to fall asleep or not being able to stay asleep. Although insomnia can be caused by a variety of factors such as stress, depression, medications, sleep disorders, and ageing; it is a logical result of an internal clock. Medications taken under proper guidance can help people with insomnia. Safer and effective medications are now also available for sleep and waking disorders. If you suffer from such a disorder, talk with your doctor and take treatment.

Insomnia in Blind

Insomnia is the most common sleep complaint of people who are blind. People who are totally blind are prone to a cyclic form of insomnia, designated in medical terminology as non-24-hour sleep-wake syndrome because they lack light input to the circadian time-keeping system. They have body rhythms that are not necessarily synchronised to the 24-hour solar and social day. In blind individuals the internal clock mechanism 'runs free' and is in and out of phase with the day-night cycle, i.e. sometimes it is in phase (harmony) with the sighted world, and sometimes it is not. A free-running clock goes by a 24-hour plus 30-minute cycle daily. It is an additional 30 minutes off with each successive day. Eventually, the clock is entirely '100 degrees' out of phase (going to bed when everyone else is getting up), before it starts back towards a normal cycle.

Sleep Problems in the Elderly

Why do the elderly have problem in sleeping (Fig. 5.4)? The

reasons can include medications, physical problems, their social setting and psychological conditions. In studies of healthy old people, scientists have shown that some circadian rhythms themselves seem to be disrupted by age. For example, the amplitudes of the body temperature and melatonin-production rhythms decrease with age, while insulin production may increase. In addition, the internal desynchronisation of a number of rhythms increases as we age. Older people might wake up earlier in the day than their younger counterparts, perhaps, because light exposure is interrupting sleep and throwing off the sleep-wake cycle. For circadian rhythms to be disturbed in the elderly, one of the possible reasons could be that humans over 80 years of age tend to have fewer SCN neurons and a smaller SCN (Fig. 5.5). Any earlier changes in the SCN before age 80 are not yet understood.

Fig. 5.4: The sleep-wake cycle gets disrupted in elderly people.

An alternative to sedative medications, which can be useless if not dangerous to older people, has recently been tried with some success. Healthy elderly patients can be given a timed exposure (from two to four hours) to bright light in the evening, resulting in improved sleep patterns—

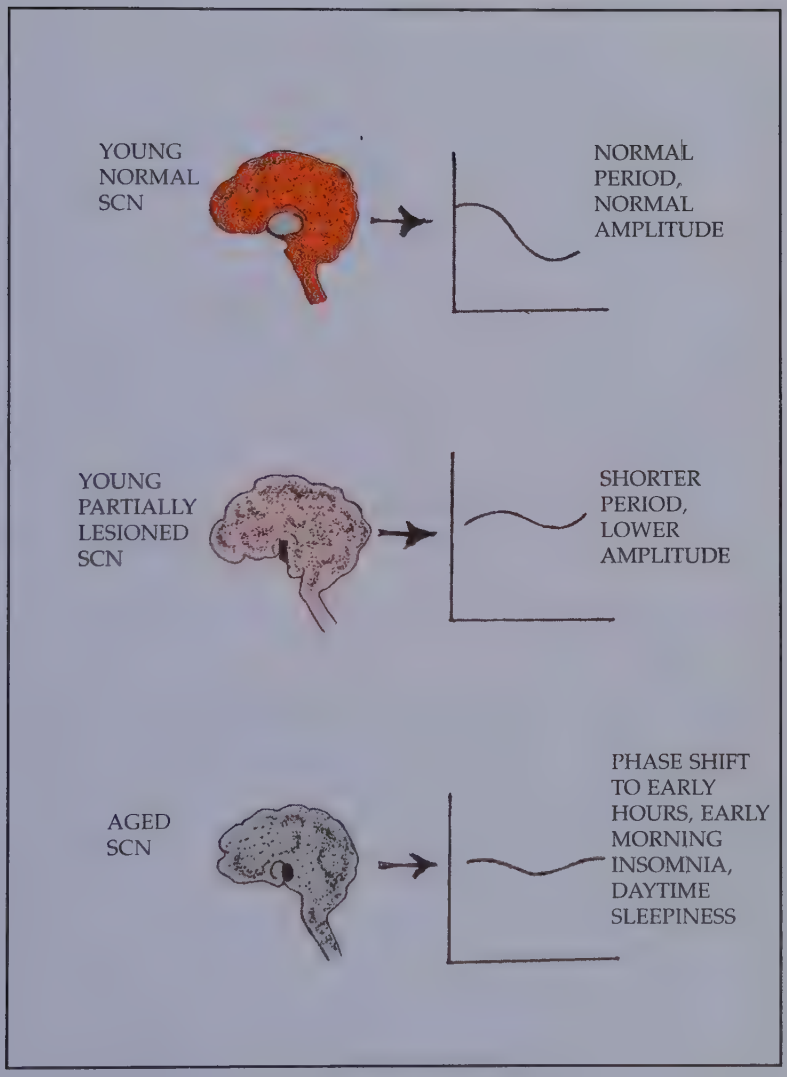

Fig. 5.5: Ageing and SCN.

less wakefulness in the night and a phase delay of several hours. However, the therapeutic use of light on the human circadian system is still experimental, and bright light sources used inappropriately may damage the retina.

Sleep Disturbances in Space

The change in sleep pattern that typically comes with ageing is early waking and fragmented sleep. In space too, sleep is fragmented or otherwise disturbed. Optimal alertness during the day and sound sleep at night require proper synchronising of the human circadian pacemaker—the 'body clock'. Researchers seek to understand how ageing and space flight affect the mechanisms governing circadian rhythms. While researchers surmise that ageing changes the properties of the body clock, they are not precisely sure how the changes occur. The fact that bright light can reset the body clock is used in treating ageing people. More recently it has proved useful to astronauts preparing for space flight.

Therapeutic Use of Melatonin

Today, melatonin, a hormone naturally produced in the brain, has become a very popular drug. People use melatonin to get sleep easily, in a large part because melatonin is available over the counter in health food, and in pharmaceutical stores. Melatonin has been getting a great deal of attention in recent years for its supposed sleep-inducing effects. As we grow older, we produce less melatonin, which may account in part for insomnia in older adults. Many people use synthetic melatonin supplements to induce sleep and to promote a sound sleep. Melatonin can be taken externally as a sleeping pill, every night before bedtime (Fig.5.6). Yet many scientists who study sleep are not convinced about the long-term consequences of taking melatonin. Researchers are unclear as to what the therapeutic effects of melatonin are or what dosage should be used. In addition, it is unknown if there are any significant side effects of melatonin in case of any interactions between melatonin and other drugs, or if people with certain medical conditions can use it. Although, some studies have demonstrated that melatonin has a positive effect on sleep, more research is needed before it can be promoted as a safe, effective sleep-aid.

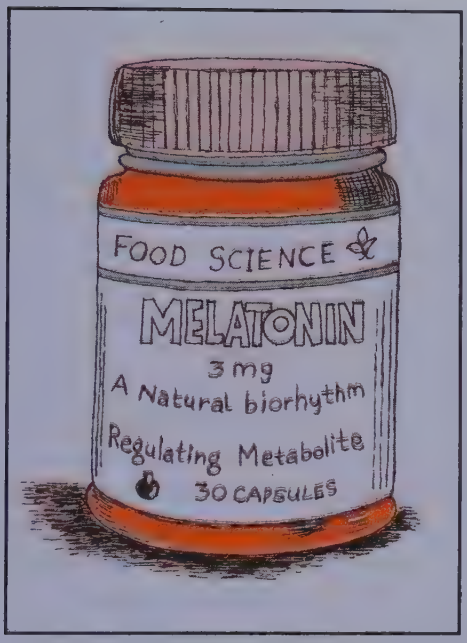

Fig. 5.6: Synthetic melatonin.

The most common side effects that melatonin can have are a groggy or 'hangover' feeling in the morning, headache, and stomach upset. Melatonin should be avoided if you are pregnant, trying to conceive, nursing, or have severe allergies or an autoimmune disease. It should not be given to children.

New studies show that melatonin can reset the body clocks in totally blind people, dramatically improving their sleep and alertness. Sunlight, passing through the eyes, synchronises most people's body rhythms with the Earth's day/night cycle. But people who cannot perceive light drift around the real-time clock, suffering recurring bouts of poor sleep and daytime sleepiness. People with sight start making melatonin about 9:30 p.m. and stop soon after dawn. The circadian cycles of blind men range from 24.2 to 24.9 hours. According to the latest research, blind people can function on a 24-hour cycle as people who can see after taking melatonin.

Seasonal Affective Disorder (SAD) and Light Exposure

We know that in addition to daily rhythms, the biological clock also regulates seasonal changes in physiology. Mammals, living in temperate zones, exhibit seasonal changes in behaviour and activity. The normal response of mammals to changing seasons is to alter their activities and

behaviours in respect to eating, sleeping, socialisation, and sexual activity.

The signal of seasonal change is conveyed by the changing day-length. In mammals this information reaches the brain by way of a non-visual neural pathway, from the retina of the eye to the internal biological clock in the brain. One function of the biological clock is to regulate the production of melatonin in the pineal gland. New studies indicate that light influences serotonergic pathways (pathways associated with the neurotransmitter, serotonin), including those, which affect mood. Therefore, light exposure has been suggested as a potential alternative to drug treatment.

Lack of light has been known to cause stress to those suffering from the following: alcoholism, premenstrual syndrome (PMS), panic disorder, bi-polar disorder, sleep disorders, and anorexia nervosa. PMS can be seasonal, or it may worsen with the seasons. Although substantial research still needs to be done in this area, clearly there is a link with the female hormonal cycle, melatonin, and circadian rhythms. Many people with bulimia (a disorder that consists of binging and purging), or those who are alcoholics or suffer from panic disorder also see an increased incidence of symptoms in the fall and winter months. Often in the summer months we feel great but in severe winter, as the stress from the lack of light takes its toll on our bodies, the control we had during the summer months diminishes. We become victims of the seasons.

Seasonal Affective Disorder (SAD)

New research has shown that sunrise is not only beautiful; it is also the key to maintaining healthy circadian body rhythms. Shorter days and longer periods of darkness change the number of hours that our bodies want to sleep. It can also be a link to depression. People can suffer from a syndrome called Seasonal Affective Disorder (SAD).

Individuals suffering from SAD syndrome experience

a variety of symptoms including the winter 'blues'—depression during winter season. Early morning nasal congestion, carbohydrate craving, weight gain, low productivity, reduced capacity to concentrate and other complaints are common among people with SAD, which seem to have roots in poorly synchronised circadian rhythms. Seasonal changes in light exposure may partly be the cause. Since light can be used for treatment of SAD over the years, researchers have been evaluating human subject responses to simulated sunrise or 'dawn simulation'. Studies funded by the National Institutes of Health, carried out by Dr David Avery of the University of Washington, are under progress to scientifically determine if dawn simulation can successfully mimic the circadian rhythm timing characteristics of real dawn. The results may be encouraging. Dawn simulation may be able to entrain the body rhythm to a stable work-day, rather than the solar day, that changes seasonally. Instead of experiencing seasonal ups and downs, we may be able to maintain a steady-state body rhythm all year long.

Dawn simulation includes specially programmed 'sun up' dawn simulators, that administer either accurate or placebo 'dawns'—morning light to people with symptoms of SAD. The first five years of trials using dawn simulation have met with remarkable success, reducing depression within a few days. What is most exciting is that while drugs may take up to two weeks to help, the bright-light boxes take only one week to get rid of the symptoms.

Light Therapy

Light therapy or phototherapy is more widely used to treat SAD, but it is also an effective method of adjusting sleep-wake timing. Particularly promising is phototherapy treatment for premenstrual syndrome (PMS). The principle behind phototherapy is that exposure to light in the morning advances the sleep phase, whereas light in the evening delays it. Light therapy is often used to synchronise sleep patterns with the external day and night. In people with a

delayed circadian rhythm, the internal biological clock can be shifted to an earlier position and aligned with the external environment through exposure to appropriately timed light in the morning. Similarly, for people whose internal clocks are set too early, the internal clock can be shifted to a later time with evening light exposure. The timing of light treatment with respect to the position of the internal clock is critical. People with delayed or advanced sleep-phase syndromes would be well advised to consult a qualified sleep therapist before embarking on a programme of light therapy.

Light therapy is being successfully used to treat a wide range of mental, emotional, and physical problems and for developing human potential. The therapies are:

- Relaxation.
- Meditation.
- Treatment of Seasonal Affective Disorder (SAD).
- Stress relief.
- Self-hypnosis for self-healing and self-education.
- Compensation for changing sleep patterns: maintaining circadian clock when affected by insomnia, jet lag, shift work.
- Cognitive therapy.
- Coping with anxiety disorder.
- Creative thinking.

For light therapy, a source of very bright light is needed. Room lighting is not bright enough. Sunlight is good, if there are lots of windows or if it can get inside. You should never look directly at the Sun, of course. White light is usually more appropriate than other colours; soft light is more likely to help in reducing stress than harsh bright light; and duration of exposure is mostly a matter of personal preference. The positive experiences of tens of thousands of satisfied individuals who are using some kind of light therapy system validate this view. Use of supplemental light has positive effects on many persons in alleviating

various seasonal and emotional stresses.

Most convenient is an electric light box or light visor, available from medical supply stores. A good light source will have the UV radiation filtered out. Remember that the intensity of light drops off exponentially with distance from the source. For example, if we double the distance between the light source and our eyes, the dose we receive is reduced by 75 per cent. Treatment effectiveness also increases (up to a point) with the length of exposure of about 30 minutes to two hours. Most people require only one phototherapy session a day. The length of that session depends on the intensity of exposure. Currently the most commonly used light box is 10,000 lux. Lux is a measurement of light intensity from a specified distance. At 10,000 lux the average session is 15 to 45 minutes. At 5,000 lux the average session is 30 to 90 minutes.

When light enters the eye, millions of light- and colour-sensitive cells, called 'photoreceptors', convert the light into electrical impulses. These impulses travel along the optic nerve to the brain, where they trigger the hypothalamus to send chemical messengers, called 'neurotransmitters', to regulate the autonomic (automatic) functions of the body. The hypothalamus is a part of the endocrine system whose secretions govern most body functions—blood pressure, body temperature, breathing, digestion, sexual function, moods, the immune system, the aging process, and the circadian rhythm. Full-spectrum light (containing all wavelengths of visible light) sparks delicate impulses that regulate these functions and maintain health. Daily exposure to sunlight or to full-spectrum white light has been known to eliminate SAD symptoms. Delayed sleep phase syndrome (DSPS) may also be treated with light.

By getting a dose of light therapy in the morning, the day starts earlier and patients fall asleep earlier at night. Light therapy early in the night works similarly for those who fall asleep early and wake early, allowing them to sleep later. Light exposure timed just before the middle of the night

is most effective in delaying the sleep phase, and light timed just afterwards is most effective in advancing it. Light therapy for DSPS should begin as soon as you can get up in the morning. Minimising the exposure to light in the evening may also be helpful.

While in most mammals long-day and short-day behaviours can be induced in the laboratory by leaving room-lights on for longer or shorter periods of the day, normal levels of indoor light do not appear to strongly influence the internal biological clock in humans. Until recently it was thought that high intensities of artificial light were needed to influence the biological clock in humans. Recent research supports earlier studies that lower intensities of select wavelengths (colours) are capable of stimulating the biological clock in humans to the same extent as high intensities of white light. Phototherapy lamps use a unique patented technology to reproduce the effect of high-intensity light, without the discomfort and potential hazard to the eyes associated with 'bright light' therapy.

As lamps also screen out the hazardous wavelengths of visible light, people, whose conditions make them sensitive to eye damage can use them, especially those with pre-existing ocular (eye) conditions, or those suffering from diabetes or other diseases that predispose them to retinal damage, or those taking photosensitising medications as remedies.

As every treatment or therapy has a dark side to it, so does the light therapy. It may have some disadvantages.

Disadvantages of Light Therapy

- Certain medical conditions, such as skin or eye disease and medications are incompatible with light therapy.
- Light therapy may cause headache. So avoid reading or having to focus your eyes during the light exposure.
- Over-dosage can make you feel 'over-stimulated' or hyperactive. If this happens, decrease the time or intensity of the light treatment.

- The long-term effects of bright light treatment are not yet known.
- It may take a few days to two weeks to take full effect and adjust to the light therapy schedules. During this period, you may feel sleep-deprived.

Alertness

How alert are you at this very moment? Are you wide awake and fully focused on reading this page? Is your mind beginning to wander? Or, are you fighting sleep? Now, consider your alertness level during a typical work-day. Obviously, that level varies throughout the day or night. We all strive to operate at the upper end of the human alertness scale, fully focused on the task at hand. Whether we are successful depends on a number of factors—some biological and some environmental. Ironically, many traditional work environments and management philosophies actually run counter to alertness. For example, light, temperature and noise levels in offices and control rooms are kept optimal for computer operation and human comfort, but they are not optimal for operator alertness. In fact, they are often conducive to sleep. How many times have you found yourself staring at a computer monitor, lulled by the quiet hum of the machine, barely able to keep your head from dropping onto the keyboard? The consequences of fatigue-induced 'micro sleeps' are quite serious when your computer is helping to monitor a safety critical industrial operation, or if you are at the controls of a car, an airplane, truck, locomotive or ship.

Due to our circadian rhythms, we generally experience peak levels of alertness in the morning and early evening. Times of low alertness emerge during the overnight hours—midnight to dawn and the early afternoon—the 'post-lunch dip'. How long you have been awake and how much sleep you have had in recent days also affects your alertness level. When you are sleep deprived for several days, you build up a 'sleep debt' that leads to a reduced alertness.

A long spell of sleep acts as a 'deposit' that offsets your sleep debt.

Long and irregular working hours are often associated with shortened sleep and reduced alertness levels. Our bodies are programmed for sleeping at night and being awake and active during the day. Night-work requires us to sleep during the day, and unfortunately daytime sleep is often shorter and its quality is not as good as night-time sleep. Generally, alertness and performance are lower when working during the night as compared to the day.

Your alertness level is constantly fluctuating. However, there are factors that control your level of alertness at any moment in time. These include interest, opportunity or sense of danger. Nothing pulls us faster from a drowsy state than the imminent threat of danger, or just surviving a near miss. A stimulating job also boosts alertness. Muscular activity, such as walking or stretching, triggers the sympathetic nervous system and helps keep you alert. Sitting in a comfortable chair can make it hard to stay awake.

Certain foods and substances, such as caffeine, nicotine and amphetamines, for example, temporarily increase alertness. Others such as warm milk, bananas and sleeping pills, etc. induce sleep. Bright light around you tends to increase alertness while dim light leads to drowsiness. Cool, dry air, especially on your face, helps keep you alert, while heat and humidity make you drowsy. The sound of rolling waves on the beach or the hum of white noise from machines can lull you to sleep. Irregular or variable sounds, such as that of a radio, conversation or a honking horn, stimulate alertness. Studies have demonstrated that some smells like peppermint, make people more alert; others, like lavender, have a sedative effect.

An interesting truth about alertness is that it is sometimes incompatible with comfort. In fact, to be fully alert, we may need to be a little uncomfortable at times. Too often people performing important tasks try to make themselves comfortable. However, when alertness sags,

dangerous events such as micro sleeps and automatic behaviour occur.

Micro Sleeps

Micro sleeps are brief, unintended episodes of loss of attention associated with events such as blank stare, head snapping, prolonged eye closure, etc. which may occur when you are fatigued but are trying to stay awake to perform a monotonous task, like driving a car or watching a computer screen. The most obvious example of micro sleep is an event people often refer to as 'nodding off'. Micro sleeps intrude in the midst of an ongoing wakeful activity and typically last between two and 30 seconds. It has been found that micro sleep episodes are most likely to occur at certain times of day, e.g. pre-dawn hours and mid-afternoon.

When a person whose brain waves are monitored by an electroencephalogram experiences a micro sleep event, a very characteristic person-specific EEG pattern shows up. In many cases, these characteristic EEG micro sleep patterns can be detected even before a person shows any clear signs of fatigue. An early detection of micro sleep could prevent many serious accidents. Micro sleeps are common among sleep-deprived people in monotonous situations. Most control room operators, truckers and locomotive engineers experience them at some point, often without being aware of the event, creating potentially dangerous situations. In a micro sleep the person will not see a red signal light or notice that the road has taken a curve.

Automatic Behaviour

Automatic behaviour syndrome refers to a period of several minutes or more during which a person is able to continue performing routine duties, but is incapable of active cognition. Examples of automatic behaviour include a locomotive engineer who can continue pressing a safety lever at regular intervals, but does not notice an obstruction on the track or a trucker who keeps his rig on the road but misses his

intended turn. Automatic behaviour is more likely to occur when a person is sleep deprived or has a sleep disorder, and the victim usually has no memory of the incident. A person's eyes remain open during this automatic behaviour or 'zombie' state. Automatic behaviour and micro sleeps are some of the reasons why fatigue is so dangerous and causes so many industrial and transportation accidents.

Napping

An interesting bump in the curve of human sleep-wake cycle sometimes appears at the time when a period of anytime sleep, called 'nap', occurs (Fig. 5.7). Research shows that napping is a common feature of an healthy adult's sleep-wake behaviour, even when no sleep debt was incurred the night before the nap. All of us may not require naps. Apparently, napping can be easily suppressed, such as when one is at work, mostly because naps "tend to occur as transient events in an otherwise rising circadian function of behavioural and physiological activation." In 1994, scientists discovered that neither the duration of the main sleep or the circadian cycle is affected by napping.

Fig. 5.7: Napping in the office.

Sleep experts agree that naps should either be relatively short from 0 to 30 minutes or very long, about 90 minutes. These recommended lengths are designed to minimise sleep inertia—the temporary grogginess and disorientation people often experience when they wake up from deep sleep. We know that sleep has

five different stages—stages 1 to 4 and Rapid Eye Movement (REM). Usually it takes about 30 to 40 minutes to enter the deeper sleep stages (stages 3 and 4). By taking a 20 to 30-minute nap, you avoid entering the deeper stages of sleep and are likely to wake up from sleep stages 1 or 2, feeling alert and refreshed. This does not mean a nap should never exceed 30 minutes. When you are seriously sleep-deprived and have the opportunity to sleep longer, then the best nap length is multiples of 90 minutes—the duration of a full sleep cycle. After each cycle, you re-enter a phase of light sleep. With a 90-minute nap, you will also wake up from sleep stages 1 or 2, feeling alert and refreshed.

Even if you time your nap-length well, you may still experience some sleep inertia, so it is a good idea to give yourself 10 or 15 minutes to clear your head before driving or doing anything potentially dangerous. You might also do the things that you would usually do when you wake up, such as washing your face and having some coffee or tea. However, there is a tremendous variation among individuals. Some people can never nap at all times while others have no trouble napping at any time of the day, and some people are fond of hour-long naps. By trying different nap times and lengths, you can find the napping strategy that works best for you.

Taking a nap may need making your bedroom as dark and quiet as possible and avoiding caffeine, exercise and heavy, greasy food for several hours beforehand. You may want to use a 'white noise' machine, such as a fan, to mask outside sounds. It is more difficult to get good sleep when it is too cold or too warm. You may also want to use eyeshades and earplugs. When possible, avoid caffeine and alcohol for three to four hours before a nap. Caffeine is a stimulant, and it will make sleeping difficult. Alcohol affects sleep quality and makes it difficult to maintain sleep. Also, avoid exercising just before taking a nap because it stimulates your cardiovascular system, temporarily making you more alert.

Because of ups and downs in your circadian rhythms,

certain times are better than others for napping. During the day, the best napping time is in the afternoon, from about 1 to 5 p.m. Conversely, it may be difficult to nap between 7 and 9 p.m. because human alertness tends to rise in the evening. These timings may shift after you change your wake-up time.

Fatigue

Fatigue has been one of the main contributors to many known disasters:

Chernobyl – large area of Ukraine, Russia at 1:23 a.m.

Bhopal – Madhya Pradesh, India at 12.40 a.m.

Three-Mile Island – nuclear power plant in Pennsylvania, USA at 4:00 a.m.

There is a common but often unrecognised thread that links the Bhopal chemical plant leak, the Chernobyl nuclear plant explosion, the Three Mile Island nuclear accident, the space shuttle Challenger explosion, and possibly, the Piper Alpha disaster and countless tragedies on motorways and worksites throughout the world. That thread is mental and physical fatigue, and it is strongly impacted by the time of day. Each of these disasters involved decisions made by sleep-deprived people, or occurred during the night—a period of time when human alertness, vigilance and cognitive reasoning are typically at their lowest ebb.

What role, then, does the biological clock play in accidents? Has fatigue something to do with these mishaps? Researchers have found that the neural processes controlling alertness and sleep produce an increased sleep tendency and diminished capacity to function during certain early morning hours between 2 to 7 a.m. and, to a lesser degree, during a period in the mid-afternoon between 2 to 5 p.m., whether or not we have slept. Several studies of single-vehicle car accidents that have been judged to be fatigue-related have shown two peak times for accidents—a major one between midnight and 7 a.m.

Research has shown that automobile drivers, especially

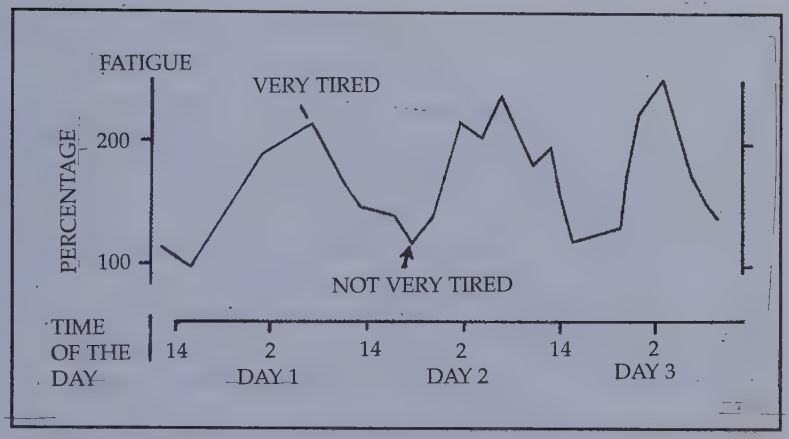

Fig. 5.8: Feeling of fatigue in individuals after 72 hours of sleep deprivation.

the truck drivers, are susceptible to both sudden fatigue due to temporary irregularities of the sleep cycle, and accumulated fatigue due to long working hours (Fig.5.8). In fact, most accidents occur between 2 and 5 a.m., well within the time span when drivers are most likely to fall asleep. Studies suggest that as many as 50 per cent of fatal highway accidents are caused by drivers falling asleep or briefly dozing off behind the wheel. Surveys of motorists show that at least a third have experienced episodes of dozing off behind the wheel; the ratio jumps to 80 per cent for people who work round the clock.

Accidents can occur because of faulty equipment, weather conditions, human error, or from a combination of causes. Diminished performance is not the only problem caused by being out of phase with one's environment. Worker and public safety also can be compromised. But fatigue and sleep deprivation are almost certainly major hidden factors of the human errors that result in accidents. Fatigue is a feeling of lack of energy, weariness or tiredness. It is not the same as drowsiness, but the desire to sleep may accompany fatigue.

One sign that shows you are fatigued is a yawn.

Yawning could also be a sign of sleepiness. We yawn generally when it is very late and we are tired, and also in the morning when we get up. The most popular theory behind this is that yawning causes us to take a deep breath when we need some extra oxygen—perhaps because we are tired and have not been breathing enough. But yawning occurs only when we are tired and does not occur at other times; for instance, following some exercise we experience laboured breathing and we do not yawn! Interestingly, nearly all vertebrates yawn, including fish, allegators, turtles, etc. In addition to yawning, apathy, the feeling of indifference may accompany fatigue but may also exist independently. Fatigue thus represents a normal and important response to physical exertion, emotional stress, or lack of sleep.

Factors Contributing to Fatigue

- Not getting enough sleep.
- Sleeping during the day, when our body rhythms promote alertness.
- Working at night, when our body rhythms are geared for sleep.
- Working irregular hours.
- Health problems, workload, work environment, etc.

When we are fatigued, our alertness is reduced, resulting in slower reactions, poor decision-making and increased errors. This may compromise our safety, both at work and at home. In addition, chronic sleep deprivation has a negative effect on our health. A pre- or post-work nap can mean the difference between falling asleep when we do not want to; for instance, while working or driving and feeling alert through the difficult overnight and early morning hours. A balanced diet, a programme of regular exercise (within prescribed limits), and adequate rest are recommended. Set priorities, maintain a reasonable schedule, and develop good sleep habits to avoid fatigue. Taking stimulants does not work and can actually make the problem worse,

especially when the drugs are discontinued. Tranquillisers generally intensify fatigue.

Shift Work

Shift work is a necessity in an industrially developed country. Manufacturing, transportation, and health care rely on shift workers to maintain operations round the clock (Fig.5.9). A shift worker can be defined as someone who works evenings, nights, rotating shifts or extended shifts. Do these workers have any special problems that might be attributed to circadian disruption?

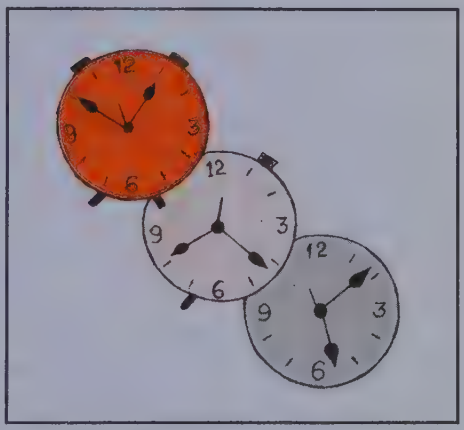

Fig. 5.9: Shift workers work round the clock.

Unlike jet lag, which is usually a temporary disruption, shift work schedules and their disruptions can last for years. Humans are diurnal creatures (active during the day), and shift workers are often out of sync with environmental and social cues. Circadian adjustment to a new shift is gradual (taking a week or more), and changing to a new shift before adjustment can cause perpetual desynchronisation. Research shows that shift workers suffer from sleep disruption and fatigue, domestic disturbances, and health problems such as gastrointestinal disorders and increased risk of cardiovascular disease. Task performance is also poorer at night. Disruptions in the circadian rhythm can lead to feelings such as tiredness, irritability, mild nausea and loss of appetite until the body adapts to the changing sleep-wake cycle required for different shifts. These ill effects are similar to the jet lag experienced after flying across

time-zones. Meal times and the quality of food consumed are also affected by changing work hours.

How can the circadian disruptions caused by shift workers be minimised? Many large companies employ advisors who advise these individuals on how to manage or prevent problems caused by shift work. Other than adjusting schedules, it is important to implement educational and support programmes regarding biological rhythms, sleep, and family counselling as a good way to improve the coping ability of shift workers. Eating regular meals with a balanced diet helps. One should consider having a largest meal after day-sleep and have a light meal in the middle of night-shift. If you are a shift worker, stick to a sleep-friendly diet that avoids greasy food, especially at night and avoids too much coffee, tea or other caffeinated drinks, especially near the end of the shift. Sunlight plays a significant role in regulating our circadian rhythm, which affects the sleep-wake cycle. Exercise regularly, but not before going to bed. Exercise too close to bedtime will keep you up; not settle you down. It is best to give yourself four to six hours between exercising and bedtime. Regular exercise contributes to easier, deeper sleep, and helps in managing stress, anxiety and depression.

It will help if you take a nap of one to four hours before the first night shift. After the last night shift, have a short sleep first, and go to bed early that night. Suggestions for anyone having trouble sleeping are to sleep in a cool, quiet, darkened room. Consider taking a hot bath or shower before bed. Develop a bedtime ritual that lets you start relaxing and sets the stage for going to sleep. Sticking to this routine sends the signal to the brain that you are preparing to go to sleep.

Staying Awake at the Wheel

If you work during the overnight hours, or party through the night, the most dangerous part of your workday is likely to be your early morning drive home from work, whether

you work in an office, a hospital or a factory. After staying awake all night, you face a serious risk of falling asleep at the wheel. Studies have found that the auto accident rate increases during the early morning hours and that shift workers and night-time bus drivers are at a higher risk of falling asleep at the wheel than the nine to five-goers. Three risk factors combine to make your journey home potentially hazardous. First, people who work at night or freak out at night generally get less sleep than others do. So it is quite possible you are sleep-deprived—a risk factor for nodding off at the wheel. A second factor is how long you have been awake. If you sleep until 2 p.m. and get up to work at 7 a.m., you are driving home after being up for 18 hours. That is nearly twice as long as a daytime worker who wakes at 7 p.m. and drives home possibly at 6 p.m. The third factor is the circadian component. Our body's circadian rhythms make it particularly hard to stay alert between 2 and 6 a.m.; and even at 7 or 8 a.m. your alertness level is still much lower than it typically is at other times of the day.

Drive Safely

- Get enough sleep. A safe drive home begins well before you ease yourself into the driver's seat as the Sun comes up. To avoid attention lapses on the road, you need to get enough sleep. If you cannot sleep a full eight hours at one stretch, the normal sleep time, then supplement your main sleep period with naps. Be aware of the accident risk. Recognise that you can fall asleep at the wheel. You need to be conscious of the three risk factors discussed above. For example, if you only got three hours of sleep yesterday and you did not have a chance to take an afternoon nap, an alarm should go off in your head warning you that you are at a higher risk than usual.
- Take a nap. Apart from letting someone else drive or checking into a hotel, taking a nap before you drive home is the number one thing you can do to reduce

your accident risk. You are sleepy, so a dose of sleep is the best 'cure'. After taking a 15 to 20-minute nap, you should feel refreshed and capable of driving safely.

- Use caffeine wisely. Caffeine is a double-edged sword. On the plus side, it does boost your alertness and performance, generally about 30 minutes after you ingest it. On the flip side, it can upset your stomach and make it harder to sleep once you get home. Although it may be helpful in an emergency, you should not rely on caffeine to get you home safely after work.
- Better to car-pool. Having someone to talk to keeps your mind engaged and reduces the likelihood that you will fall asleep at the wheel. Just remember that this only works as long as your passenger is awake!

Popular measures such as turning up the radio, blasting the air-conditioning, opening the window, taking off your shoes, slapping yourself in the face provide little or no benefit. In fact, they may actually leave you worse off because they can give you a false sense of security. Driving while drowsy (D.W.D.) can prove dangerous. Public awareness of the dangers of mixing alcohol with driving has risen dramatically in recent years. Sleep experts say drowsiness affects your ability to drive in a fashion quite similar to alcohol, such as slowed reaction time, decreased awareness and impaired judgment with equally harmful risks and consequences.

Jet Lag

It seems like a cruel trick, doesn't it? There you are, the Sun shining down upon you as you gaze at the site of the ancient pyramids outside of Cairo, or munch on a croissant on the Champs Elysees in Paris—and all you can think about is getting back to bed. Anyone who has travelled long distances knows the havoc jet lag can wreck on those first few days of vacation. Your mind and senses may be excited by your new surroundings, but your body is in sluggish

rebellion. You may be irritable, depressed with head aching and unable to concentrate. Worse yet, a weakened immune system could make you vulnerable to a cold or flu. This could be due to jet lag or a state of fatigue. For the veteran business traveller it can range from a minor inconvenience to a major threat to performance. Jet lag may impair your judgment, performance and decision-making. If you are flying to a resort to relax, you may not care; but you might care if you are travelling to negotiate an important deal. Your jet lag could have a significant effect on the outcome. Why do travellers flying cross-country suffer from fatigue, gastro-intestinal complaints, and shortened attention span just from flying across a few time-zones? Sleep loss alone could not account for their interrupted circadian rhythms.

What you might not realise is that several different factors related to travel contribute to the development of the symptoms of jet lag. Understanding each of them may help you protect yourself against their effects the next time you travel. Due to variations in individuals, some people feel jet lag effects more than others. Jet lag occurs because of a conflict between the traveller's own circadian clock and external rhythms in a new time-zone. The timing of meals, activity, and sleep no longer coincides with what is customary in the new time-zone. Furthermore, environmental cues, especially light, promote synchronisation between circadian rhythms and the new time-zone. Since different circadian rhythms may adjust to the new time-zone at different rates, the traveller experiences a period when internally generated rhythms are no longer in synchrony with each other.

The symptoms of jet lag include fatigue, lack of sleep, stomach ailments or even nausea and headache. Certain factors aggravate jet lag symptoms. These include travel fatigue, external desynchronisation, internal desynchronisation and disruption of sleep patterns.

Symptoms that Aggravate Jet Lag

Travel fatigue: The initial packing, getting to the airport hours

before the scheduled flight time, reaching the destination amidst heavy traffic, waiting in queues to check in your baggage, passing through heavy security checks and then waiting at the stuffy gate before cramming onto an airplane, is in itself 'travel fatigue'. By the time you arrive at your destination, you are more than ready for a long night's sleep in order to recover. Only if you are able to time your flight optimally, such a condition may work to your advantage.

External desynchronisation: You leave the plane to prepare for breakfast, but it is dinnertime at your new location. It is dark outside, the traffic is light, the shades are drawn across apartment windows, no birds are chirping in the Sun, and the daily newspaper will not be delivered for another nine hours. You feel disjointed, somehow a little confused, unsettled, and these feelings further progress after you arrive at the hotel and try to sleep when your body urges you to stay awake. This feeling of being out-of-sync with your environment is itself a symptom of jet lag.

Internal desynchronisation: In addition to feeling 'dislocated' because your sense of what time it is differs from the real time in your new location, you also have to cope with a very interesting, and little known side effect of time-zone travel: internal desynchronisation, the disruption of your carefully orchestrated biological rhythms. Many of your physiological functions, such as the heartbeat and respiration rate have their own daily rhythms, which are kept in sync by your internal clock. When time-zone travel disrupts this clock, not only are your sleep-wake patterns disrupted, but these rhythms also become desynchronised, one from the other, which contributes to your feelings of malaise. Constipation and other symptoms of gastrointestinal distress, headaches, and irritability are just a few of the resulting symptoms. It can take several days for your body rhythms to readjust and run smoothly, in harmony with your new environment.

Disturbances in Sleep Patterns

Disruption of sleep-wake cycle is the foremost casualty problem for all travellers. Not only may your body be telling you to stay awake during local daytime, but also anxiety, stress, fatigue, and excitement, all act together to disrupt this cycle. Many travellers, for instance, have more trouble getting to, and staying asleep, no matter what time it is locally or internally. When the temperature cycle is in one time-zone, the sleep-wake cycle quickly catches up to the new time-zone; but all the other human systems are scattered somewhere else.

Fig. 5.10: Travellers crossing time-zones in airplanes.

Other factors too influence the degree to which a traveller feels jet lag, such as age, direction of travel (going west is better than going east), number of time-zones crossed (Fig. 5.10), and factors specific to the individual. As you may have experienced yourself, the direction of the flight you take significantly influences the degree of jet lag you feel. When you are eastbound, or against the direction of the Sun, jet lag tends to be more severe than when you fly west. This is because while flying westward, you are allowing your body to follow its natural inclination to extend the day to about 25 hours. It is morning when you land in New York and you are yawning and feeling terribly sleepy. Your bedtime shifts forward, later and later; for instance, if you fly from New Delhi in India to New York in USA, within a few days' time, without even trying, your bedtime would quickly shift so that you go to bed on New York time. By travelling east, on the other hand, you are forcing your body to go against its natural tendency. But if you are flying from New York, travelling back to New

Delhi, then, your body will want to extend the day when, in order to catch up, you would be best served by going to bed earlier than your body might prefer. You might feel sleepy in the afternoon, stretching across until late evening and staying wide awake during the night.

Here is an interesting example of a study of the 1991, 1992, and 1993 records for 19 major league baseball teams in the Eastern and Pacific time-zones of North America. Those teams that travelled west to east tended to lose the games they played far more often than those who travelled east to west. The home team won 56 per cent of the games, said the researchers, but the probability of winning depended on whether the visiting team had just travelled eastward. Nevertheless, no matter whichever way you are travelling, for how long or how far, you are bound to feel some ill effects. You can help to minimise these effects in two ways: by preparing as best you can for your journey and, at the same time, by working to readjust your biological clock as efficiently as possible.

Coping with Jet Lag

Under normal circumstances, the human body's circadian (or biological) clock naturally runs on about 25-hour day. Each day, morning sunlight and other time cues reset our clock by an hour to keep it in sync with the external environment. Most people can adjust to this one-hour shift with ease. When we travel across multiple time-zones, we can exceed the ability of our circadian clock to automatically adjust and experience the phenomenon of jet lag. This is particularly true when travelling from west to east, which has the effect of shortening the day.

Making it through your journey, feeling healthy and vital is an important aspect of travel. You also need to speed the rate at which your internal clock adjusts to the time in your new environment. No matter what you do, this process takes at least a couple of days, but the more quickly and well you can sleep at the local bedtime and wake up feeling

rested in the morning, the better. Your very first decision when it comes to your biological clock is whether or not you want to stay on your 'home time' or make the adjustment to your new environment. To a large extent that depends on how long you are planning to stay. If the trip is short—under three days and you have control over your time, for example, when you are on a vacation, you may be best served by maintaining your home schedules as much as possible. If you are staying longer, or have business meetings to attend that require you to be alert when you would be sleepy at home, you may want to readjust your circadian clock as soon as you can.

The best itinerary would be to arrive at your destination in the early evening, local time. That way, you will be able to get a light bite to eat, and take a walk before going to bed. The sheer act of travelling will make you feel tired even if it is earlier than usual 'body time'; you may be tired enough to sleep. If you are flying when it is night-time at your destination and it will be morning when you arrive, try to sleep on the plane (Fig. 5.11). If it is daytime, try to

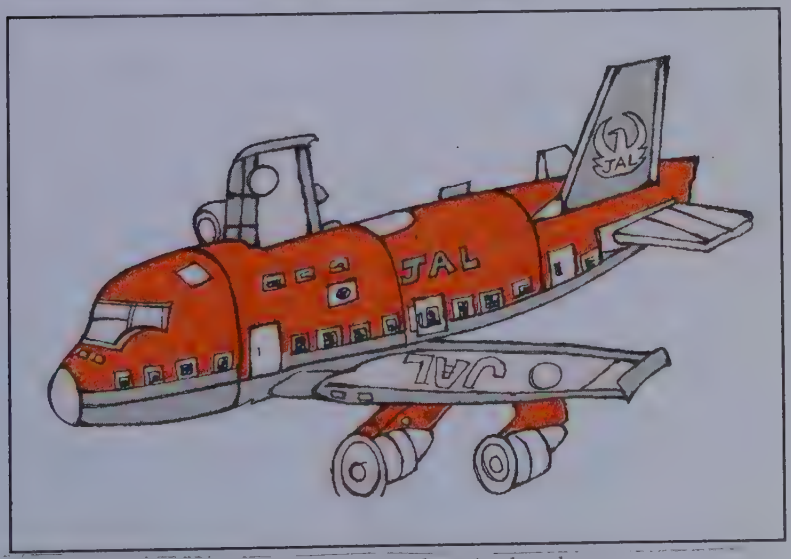

Fig. 5.11: Try to sleep in the plane.

stay awake, no matter what time your body thinks it is at the moment, or catch a 20-minute nap to take the edge off.

Timing of sleep is important, both during the flight and upon arrival. The goal is to get acclimatised to the new time-zone as quickly as possible, without affecting alertness or performance in the process. East-to-west travellers departing in the evening should make an effort to stay awake later than normal on the flight. West-to-east travellers leaving at night should try to get enough sleep so that they can be reasonably prepared to stay awake all day in the destination city. Another approach that can be effective is to start a few days before your departure by shifting your schedule to your destination's time-zone. Even shifting your circadian clock in advance by a few hours can make a big difference when it is time to travel.

Studies have shown that the food you eat does have a bearing on the severity of desynchronisation. Meal times can act as a strong *zeitgeber*, provided the meals are eaten at regular time. Meal constituents are known to affect the synchronising of circadian rhythms. Because food, drink, caffeine, alcohol and medications can affect the quantity and quality of your sleep, they can help increase or reduce the effect of jet lag. If you know that you want to get some sleep on a plane, do not eat a big dinner; do not consume caffeinated or alcoholic beverages; and watch out for medications that may have a stimulant effect. Many use alcohol as a sleep-inducing agent, but it has a negative effect on the amount of REM (rapid eye movement) sleep of individuals. REM sleep is the deep-sleep stage, therefore, alcohol consumption is not recommended during the trip. Drinking water or juice would be fine, and milk would be even better since it contains L-tryptophan—an amino acid that helps to induce sleep. While it is best to avoid habitual use of sleeping pills, this may be an appropriate measure to help you get sleep during the flight. However, the effect may outlast the duration of the flight, which may outweigh any beneficial effects. As always, you should consult your doctor

before using sleeping pills.

We have already discussed light therapy in the earlier chapter but it can be very helpful in coping with jet lag and resetting your internal clock as long as you are careful about when and how long to expose yourself to it. Exposure to bright light in the morning will help shift you forward, allowing you to go to bed later and wake up earlier in the coming days. Bright light in the evening, on the other hand, will shift you back, so that you go to bed earlier and get up later. In the evening, light has the effect of delaying the circadian clock time. Sometime between 3:00 and 4:00 a.m., when the body temperature reaches its minimum, light's effectiveness switches to advancing the circadian clock time. So east-to-west travellers leaving in the evening can benefit from exposure to bright light but they should wear dark glasses and avoid bright light, if they are departing in the morning. Conversely, west-to-east travellers should seek bright light when departing in the morning but avoid light when leaving at night. The brighter the light and the longer the exposure, the greater the resetting effect. Natural sunlight, even on a cloudy day, is bright enough to reset the circadian clock.

Another option is a portable light visor, like the ones used to treat people who suffer from Seasonal Affective Disorder (SAD or winter depression), although this should be used with proper training since misuse can create other health problems. Combined with taking a dose of melatonin at bedtime, bright light therapy can significantly speed up your period of adjustment to a new environment.

Pre-flight Tips for Minimising Jet Lag

It may be impossible for some people to eliminate all the negative effects of travel on the body and mind, but they can help minimise them by being as healthy and well-rested as possible before embarking on the plane and then by treating themselves well during the flight.

It is necessary that you get plenty of sleep before you

travel. The effects of jet lag are considerably greater if you have slept less. Not only will you feel the symptoms of sleep deprivation, such as excessive daytime sleepiness, headaches, irritability, etc., lack of sleep will also exacerbate the problems due to the disruption of your circadian rhythms.

If you are travelling westward and have some flexibility in your routine, you can try going to bed and getting up an hour later each day for three days before leaving. That way, you will be well on your way to meeting the local schedule by the time you arrive. If you are flying eastward, you can reverse the process. Allow extra time for adjustment during a trip or when switching to a new work schedule.

Diet plans have been developed which partially alleviate the effects of circadian dysrhythmia. At least three days prior to the flight day, light and heavy meals may be alternated. On the day of flying, very light meals can be eaten; at times according to the destination. These diets consist of pre-flight alteration of light and heavy meals, alteration of protein and carbohydrate ratio in meals, and the programmed use of chronobiotic drugs such as theophylline, which alter the period of timing of circadian rhythms. These are used to speed up resynchronisation after a phase shift, as they produce a rhythm phase shift in the direction of the time at the destination, which enhances resynchronisation. It is claimed that a high protein breakfast and a low protein/high carbohydrate dinner will facilitate the resynchronisation of circadian rhythms following advance phase shift by the synthesis of serotonin from carbohydrates.

In-flight Tips for Minimising Jet Lag

Airplane travel is highly conducive to dehydration because of dry air within the airplane. Dehydration results in diminished blood flow to the muscles, reduced kidney function, and fatigue, all of which exacerbate jet lag. Experts suggest that you can prevent dehydration by drinking one litre of water on every six hours of flight in addition to the

beverages you drink with meals. Even if you may not feel thirsty, it is important to drink water on a regular basis throughout the flight.

Try and avoid consuming alcoholic beverages. This is because alcohol not only affects the quality of your sleep, but also tends to dehydrate the body—the two effects you want to avoid if you are trying to alleviate jet lag.

Being active in airplane helps. Although you cannot play tennis on board, you certainly can stretch, walk up and down the aisle, and even perform some isometric exercises in your seat. This will help keep your body limber and reduce stress during a long flight.

Sleep aboard an airplane is essential, so time your sleep period well. Earplugs, an eye mask, an inflatable neck pillow, and a sweater or shawl will help make you more comfortable, and thus more likely to relax and fall asleep.

It is best to eat several small, light meals throughout the days before, during, and just following your journey. Eating a big, heavy meal will only increase your chances of suffering an upset stomach. Avoid high-sugar snacks, caffeine, and alcohol, all of which can interfere with your ability to sleep and may make you feel uncomfortable.

Post-flight Tips for Minimising Jet Lag

The occasional use of short-acting sleeping medications can help reduce the symptoms of the circadian rhythm disorder. As with so many things, people want the easiest route possible and consequently a lot of research has been done on chronobiotics. Chronobiotics are compounds that are capable of quickly shifting biological clocks and so would be very useful in alleviating jet lag by allowing the clock to adjust more rapidly. Melatonin has been proposed as chronobiotic and is prescribed as a cure for jet lag. But before taking any medications, check with your doctor. Never mix sleeping pills with alcohol or antihistamines. Keep in mind that these are for temporary use only and their effectiveness may fade within a month's time.

If you use melatonin, take a dose of it just before you want to go to bed at your destination. It may help set the stage for your body to sleep even if it's daytime back home. Never take melatonin before this point because if you do, you may end up disturbing your rhythms unnecessarily. Melatonin is a hormone that we produce naturally. Synthetic melatonin is available at many drug stores and health food stores, as a food supplement. There is a controversy about the use of melatonin as there is no universal agreement on its effectiveness as a sleeping aid or its ability to adjust your biological clock. There is also concern about the unknown, long-term repercussions of melatonin use. Consult your physician before using melatonin and try taking the minimum effective dose. Most commercially available melatonin comes in 2, 3 or 5 mg tablets but much of the research has been done using doses of 1.5 mg or lower dosage, so you may want to split tablets in half. This is because sometimes, massive doses of increase in melatonin levels can affect fertility, weaken the immune system and have serious side effects for some people, including pregnant women or nursing mothers. Others, who should be especially cautious, include children, diabetics and anyone experiencing depression or taking antidepressants. Also, anyone with an autoimmune disorder or taking an immune-suppressant medication should consult a physician before taking melatonin.

Avoid using sleeping pills because although a quick fix for a travel-related sleep problem may seem like a dream come true, but you may probably be make things worse for yourself. The 'hang-over' effect of most sleeping pills will only increase your feelings of sleep deprivation the next day, and may even make it harder for you to get to sleep the next night.

Reports suggest that acupuncture has proved effective in adapting the body clock to a different time-zone. Acupuncture treats jet lag by changing the flow of energy along pathways in the body, called 'meridians'. By stimulating a

specific combination of points, the acupuncturist can adapt the rhythms of the internal clock to the local time-zone. The treatment lasts about 30 minutes.

Napping can help make up for a sleep loss, as well as for preparing the body for a good night's sleep by taking the edge off exhaustion. Keep your naps short, from 10 to 30 minutes, and in the middle of the afternoon (local time).

Jet Lag Casualties

Commercial aviation accidents occur due to jet lag fatigue. Human error is cited as a causal factor in many fatal passenger flights. Certainly flight crews are as susceptible to fatigue as any other human. In August of 1993, a DC-8 crashed while landing at Guantanamo Bay, Cuba. The figure shows the schedule that the flight crew was assigned before the crash. Investigators concluded that the crew was so fatigued that their judgment and decision-making abilities were impaired and thus contributed to the accident. Flight schedules at times do not allow adequate rest to crews to compensate for jet lag.

In a study by the NASA Ames Research Center, USA, a flight was monitored to study the effect of planned cockpit rest on flight crews. In 12 days, the crew flew from Seattle to Narita to Honolulu to Osaka to Honolulu to Narita to Los Angeles to Seoul to Seattle—not an unusual schedule for long-haul crews. NASA concluded that there were significant positive effects on both performance and alertness as a result of the cockpit nap. Generally, the aviation people do not explicitly consider pilot duty-time, the number of time-zones crossed, and whether crew rest preceded flight duty. But the cockpit crew does require nap-time and rest.

Thus it only makes sense that if the loss of sunlight is the cause of the problem, then adding sunlight should solve it. We cannot control the progression of the Sun from season to season, and the shortened days and lengthened nights, although we can fool our body into thinking we have.

6

INFLUENCE ON BODY SYSTEMS

Of themselves, diseases come among men; some by day and some by night.

—Hesiod, Greek poet, in 700 B.C.

The 17th-century English physician, Thomas Sydenham, went to bed and slept in good health. About 2 o'clock in the morning he was awakened by a severe pain in the great toe; a pain that was so excruciating like that of a dislocation. A gnawing pain and a pressure and tightening followed this. Sydenham was well aware that this was gout; a disease of joints that afflicted the toes, knees and ankles but what was surprising was that it struck at an unearthly hour. It is true therefore that we humans are tuned to be born, die from a heart attack, suffer from a disease or fall asleep during one part of the day than during another.

Long before study of the brain and the discovery of melatonin, the ancient Chinese developed their own theory of our biological adaptation to the cycle of night and day. The Chinese biological clock divides the 24-hour cycle into two-hour periods, each associated with a particular organ of the body. During those two hours, the organ is believed to be at its peak, triggering a surge of energy along the pathways, called 'meridians'. For example, liver function crests between 1 a.m. and 3 a.m.; the lungs, between 3 a.m. and 5 a.m. Disorders of a particular organ are best treated by stimulating it during its peak period, or by sedating it at its lowest point, 12 hours later (a convenient option for

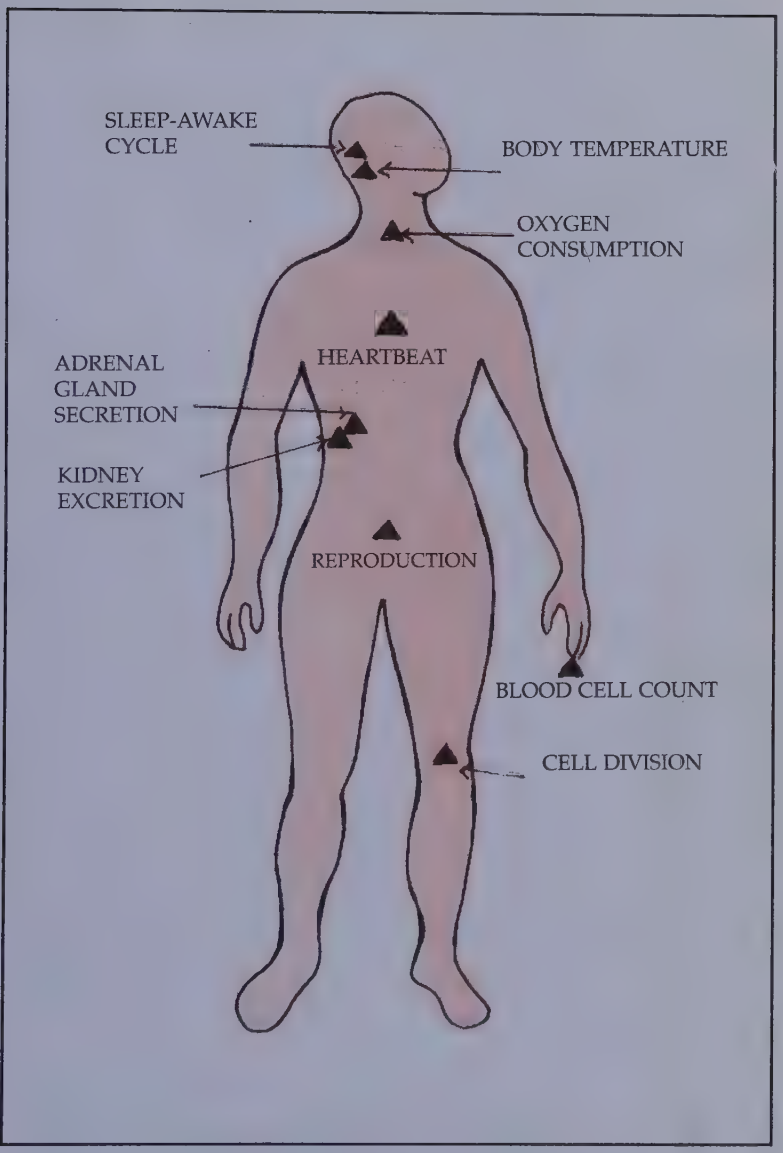

Fig. 6.1: Human body rhythms.

medical practitioners whose own biological clocks rebel against treating patients at 3 a.m.).

The body's internal clock commands an array of cycles,

varying from electrical activity in the brain to menstrual cycles and pregnancy. At regular intervals each day, the body tends to become hungry, tired, active, listless, energised. Body temperature, heart-beat, blood pressure, hormone levels, and urine flow show peaks and troughs—rise and fall in this relatively predictable, rhythmic pattern—a pattern initiated and governed by exposure to sunlight and darkness (Fig. 6.1).

The pulse normally beats 75 times a minute; the lungs fill with air at a regular tempo; even the brain thinks more clearly at certain times of the day. The sleep-wake cycle, controlled by the brain, is the most familiar biological rhythm in man; it influences the timing of many of the body's other functions. Body temperature (Fig. 6.2), regulated by the hypothalamus, varies each day, regularly falling to its lowest point during normal sleep, between 1 a.m. and 7 a.m. Oxygen increases during the normal peak hours of the body's activity—whether or not activity is present. Heart-beats normally occur 75 times a minute, but the rate drops slightly to a low point between 10 p.m. and 7 a.m. Adrenal gland secretion dips during the sleeping hours, but rises before waking to prepare the body for the day's activities. Kidney excretion of such waste products as potassium and sodium reaches its peak during the middle of the day. Reproduction is dependent on the periodic production of ova by the ovaries, in cycles of about 28 days. Pregnancy usually lasts 270 days from fertilisation to birth. Blood count has its own rhythms: the number of red and white corpuscles falls to a daily low in the morning hours of the day. Cell division, occurring throughout the body,

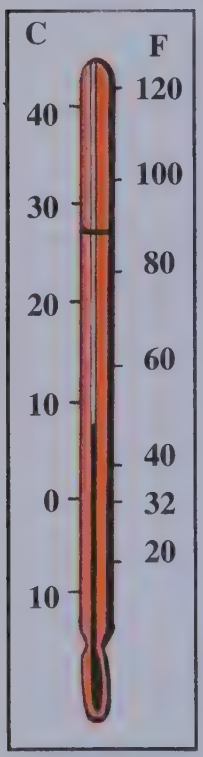

Fig. 6.2: Body measurement thermometer.

takes place most frequently during the late evening hours. All the rhythms must work in concert. If the cycles get out of step—as they do when a factory worker shifts from a day to a night shift— the resulting strain can lead to irritability and lapses in judgment.

A woman's weight, energy, mood, sleep, cravings for particular foods, and interest in sex—all vary throughout the cycle. Also, ailments such as skin eruptions, frequency of migraines, asthma attacks, and symptoms of other illnesses predictably wax and wane over the month. Numerous factors, including stress, work, sleep, diet, and even the weather, may make some months more troublesome than others. But because of the individual variation, some women suffer more intensely than others. The right time to conceive runs from about five days just before ovulation through the days of ovulation. Intercourse even a day after ovulation is unlikely to result in pregnancy. The concentration of sperm peaks in winter, so chances of conceptions increase. Research suggests that there is a universally accepted seasonal or circa-annual rhythm in the number of human conceptions each year. The highest conception rates peak in the spring with a lower peak occurring in autumn. There is also a best time of the day, i.e. the sperm travel more rapidly in the afternoon. In addition, the birth weights of babies delivered in summer and autumn tend to be on the higher side on an average than those delivered during other seasons of the year. However, our body metabolism slows down during winter, causing several people to put on a few kilos.

Changes in core temperature, the temperature of arterial blood in the central regions of the body such as aorta, femoral or carotid, is a perfect example of body rhythms. Temperatures in the oral, rectal or tympanic cavities too vary. The core temperature (Fig. 6.3) declines along the night and reaches nadir around 5 a.m. The temperature begins to rise by the time you wake up. Around 11 p.m. the temperature starts declining again and you start feeling

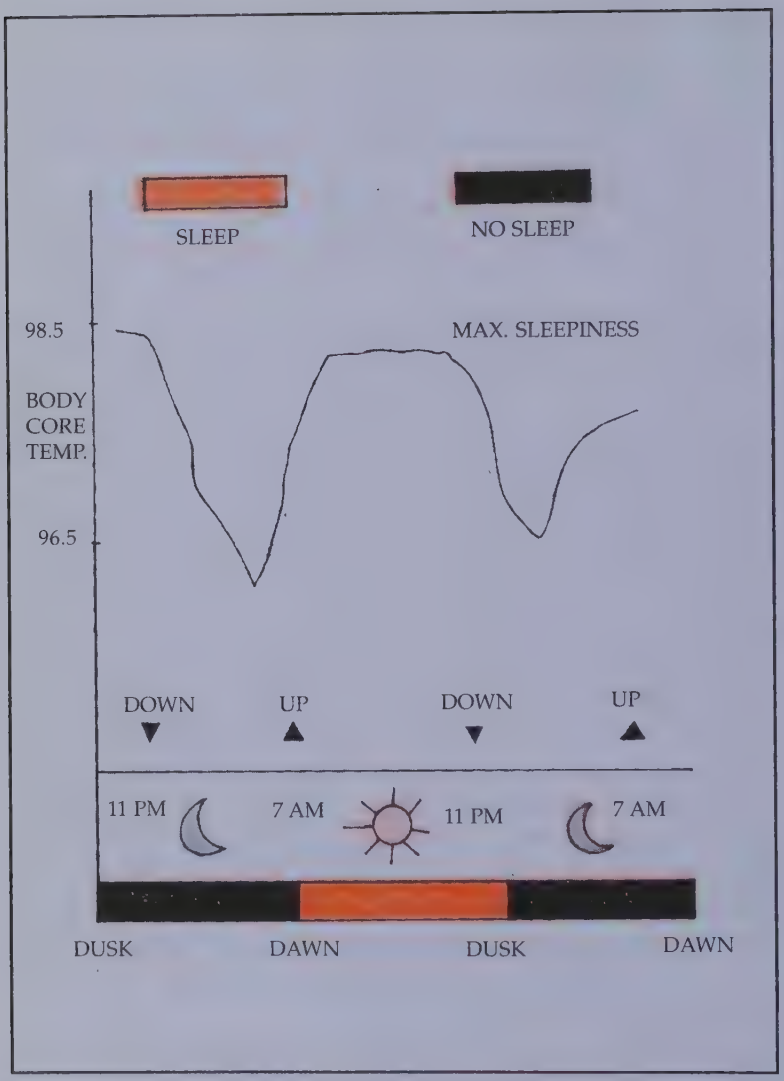

Fig. 6.3: Circadian rhythm in body core temperature.

sleepy. Around noon the temperature declines a little to make you feel 'heavy', making you take a short nap. The sleepiness will further increase if you have a big meal for lunch. The temperature will further decline if you lie down at the time; 'a post lunch dip'. However, the core temperature may show

an ideal curve if you happen to exercise or nap or eat. This phenomenon is called 'masking'.

We know that the SCN plays a role in the circadian system by triggering a neuroendocrine response in the hypothalamus, which then acts on the pituitary. This last pathway profoundly influences other parts of the body, including the endocrine, immune, cardiovascular, and urinary systems. Rhythms in most of these systems have a simple waveform, similar to that of body temperature, which is highest in the early evening and lowest right before waking in the morning. A graph showing urine volume, for example, shows a cyclic pattern very similar to that of the body's temperature. Growth hormones, prolactin, thyrotropin, and testosterone are some of the hormones that may be influenced by the circadian system. One endocrine event that clearly is under the influence of the clock is the release of the adrenocorticoptropic hormone (ACTH). The SCN triggers the hypothalamus, which activates the anterior pituitary to release ACTH, causing the adrenal glands to release cortisol and aldosterone (Fig. 6.4, 6.5). A plot of cortisol concentration in blood plasma shows a characteristic peak in the early morning (around 6 a.m.) hours, with a trough right before bedtime. Similarly, aldosterone level is constantly high throughout the night and low throughout the day.

Circadian rhythms are important for optimal functioning of many processes vital to health. Although it was thought earlier that sickness occurred at all hours of the day, human ailments do follow the rhythm of the Sun and light and darkness. They may turn more severe or are more likely to occur during one part of the day than other. And then there is the circaseptan rhythm, a seven-day cycle in which the biological processes of life, including disease symptoms and development, resolve. Many physicians believe that transplant patients tend to have more rejection episodes seven, 14, 21, and 28 days after surgery. They further believe that medications administered to the patients

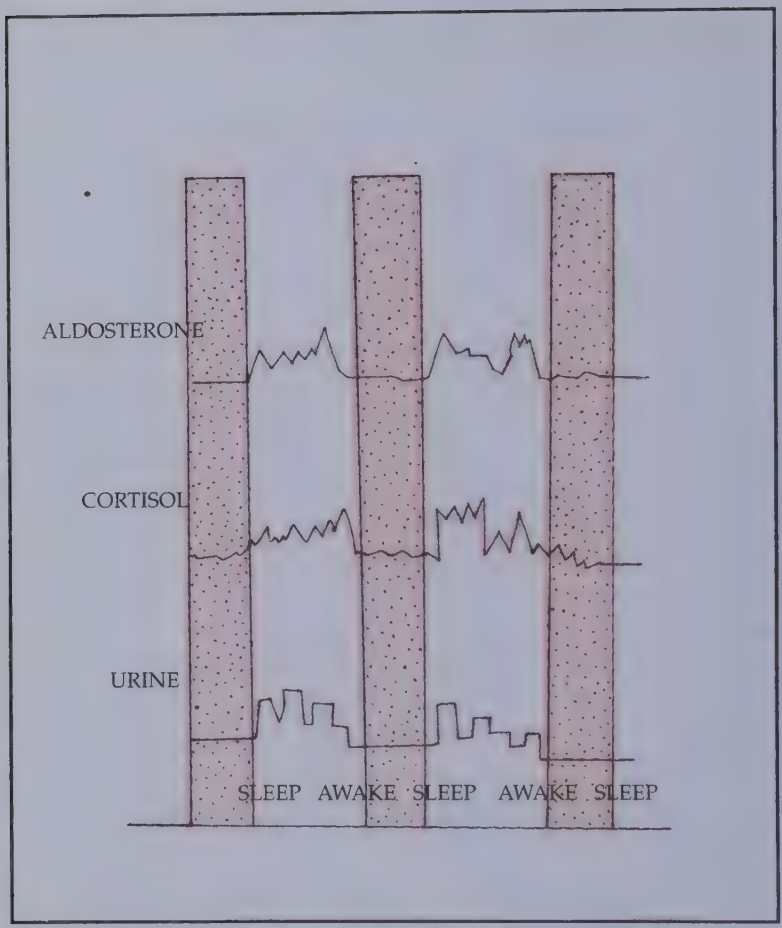

Fig. 6.4: Circadian rhythms of urine output, hormones like cortisol and aldosterone in a healthy individual.

at particular times may be more effective than at other times. These are all related to the circaseptan rhythm.

For centuries now, people have observed that hay fever that causes red, itchy eyes and stuffy nose with bouts of sneezing is bothersome in the morning, prior to breakfast and does not subside until lunch. Asthma and dyspnoea, laboured breathing attacks, strike more often during the night than during the day, perhaps due to the fluctuations

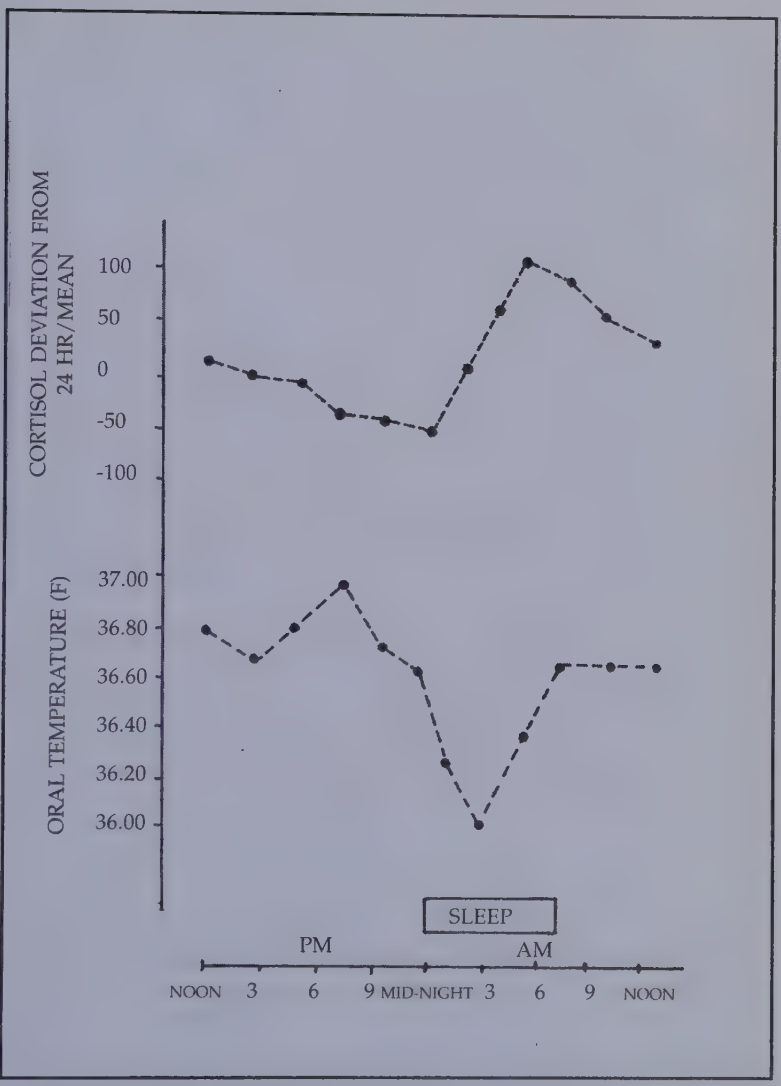

Fig. 6.5: Peaks of activity of physiological functions, such as temperature and cortisol hormone levels, vary systematically with the time of the day.

in the body's immune system. This observation has been known for centuries. "The evil (dyspnoea) is much worse in sleep....", wrote the Greek physician, Aretaeus in the third century A.D. It was in 1971, when French physician, Alain

Reinberg and Texas environmental scientist, Michael Smolensky, found that histamine, an anti-allergic substance given to asthma patients, worked well during the night than during the day. Seeing this, the doctors shifted the asthma patients into an air-filtered or air-conditioned room and isolated them completely from the outside atmosphere for the drug to work even during the day.

The scientists went on to experiment further and they filled an aerosol spray with house dust and asked the patients to inhale the dust during various times of the day. Interestingly, they discovered that the asthma patients were much more sensitive to house dust during midnight hours than they were at any other time of the day. Their study revealed that the reaction due to dust or pollen or any other allergen would depend more on the internal circadian rhythm of the sufferer's immune system, rather than the amount of the allergen.

Just as the body's sensitivity to pollen or dust has a daily rhythm, so does the pain. A toothache, for instance, is more painful during the early morning hours between 3 a.m. and sunrise than it is during any other part of the day. People wake up with migraines and muscle headaches, which also begin in the early hours of the morning.

Our body chemistry displays an evident circadian rhythm during its interaction with a host of viruses and bacteria—the eternal agitators. A series of surveys show that the onset of fever due to viral infection occurs mainly during the late afternoon and evening hours between 2.00 p.m. and 10.00 p.m. Contrarily, the onset of bacterial fever occurs during the morning hours between 5.00 a.m. and noon. The defensive system of our body, which is designed to combat these microscopic organisms, too is more active at one time than another. White blood cells, for instance, are more active during the evening hours. Activity of the immune system, as represented by the number of lymphocytes, also seems to peak in the late evening and is lowest a few hours after the cortisol peak in the morning. The timing of the endocrine

and immune systems are clearly intermeshed. It is known that aldosterone and cortisol suppress the immune system, while melatonin appears to enhance it.

The immune system is also tied to daylight. It has been understood that the daily cycle of light and dark helps reset the body's biological clock but a new study suggests that it also triggers long-term effects on our health. Researchers exposed a group of lab mice to an artificial day-night cycle and measured the activity of the mice's immune system as they did so. They found that as the days got shorter, the immune system became more active. The finding could mean that the body is protecting itself against illnesses that the mice might contract in autumn and winter and it might be important for humans who take melatonin as an immune booster. Melatonin is a light-sensitive chemical in the body, produced in higher quantities in the autumn, and it may be what activates the immune system. This active immune system is however not a permanent condition. Researchers found that even as the days remained short and the levels of melatonin high, the immune system returned to normal after a length of time.

In many other illnesses, symptoms wax and wane across the day. Take asthma, for instance. Asthma attacks occur 100 times more often between 4 a.m. and 6 a.m. than at other hours of the day. That's because the airways are most constricted in these hours in everyone, and not only persons with asthma. Airways are most relaxed around 3 p.m. In fact, this is one of the reasons why exercise is easiest in the late afternoon. If you are healthy, your airway function varies only a little from day to night, and you will not be aware of the difference. But if you have asthma, your best-to-worst airway function may vary from day to night by 50 to 60 per cent. The more variation you have, the more severe your asthma probably is. This especially is a problem for women, because asthma attacks vary over the menstrual cycle. About one in three women with asthma finds her symptoms increase right before or while she has her period.

Three out of four adults who require hospital treatment for severe asthma attacks are women, and most hospitalisations in menstrual-age women occur in the days just before or after their period starts.

Astonishingly, heart attacks, angina, strokes, all show a clear pattern of affliction. A heart attack or stroke is most likely to occur within three hours of waking. Besides the morning surge in the blood pressure, the adrenalin level and pulse rate also rise around the morning hours. Platelets too are stickier in the morning, and are more likely to clump and form deadly clots when the body's ability to dissolve them decreases.

James Muller of Harvard Medical School, USA, concluded from his study of 3,000 case files of heart patients that the chance of a heart attack striking at 9:00 a.m. was nearly three times greater than at 11:00 p.m. According to his studies, heart attacks were least likely to occur around 9:00 at night. Doctors from the National Institute of Health, USA too indicated that strokes occur around 9:00 a.m. and least likely to occur around 3 to 4 a.m. A list of death certificates of people, who died of ischaemic heart attacks where the heart muscle is deprived of blood, showed that most of these incidents occurred at around 9:00 a.m. Yet, what causes this to happen is a mystery. It could be because of the circadian rhythm of hormones and the biochemistry within our body.

There are many other illnesses where the body clock is quite important, in terms of symptoms. Some of these are fatiguing illnesses, like fibromyalgia, multiple sclerosis or AIDS. Fibromyalgia is a condition that causes pain in the muscles, joints, ligaments and tendons. You may have some degree of constant pain, but the severity of pain may vary in response to activity, stress, weather changes and other factors. Despite sufficient amounts of sleep, patients with fibromyalgia may awaken feeling fatigued, as if they have barely slept. Alternatively, they may have trouble falling asleep or staying asleep. Some also suffer from the condition

called 'sleep apnoea'. Early research in sleep labs documented disruptions in the deep (delta) sleep of some fibromyalgia patients. Multiple sclerosis (MS) is another chronic, potentially debilitating disease that affects your brain and spinal cord (central nervous system). The illness is probably an autoimmune disease, which means your immune system responds as if part of your body is a foreign substance. In the relapsing-remitting type, one or two flare-ups of MS occur every one to three years, followed by periods of remission. The flare-ups typically appear suddenly, last a few weeks or months and then gradually disappear. Symptoms may accumulate with each recurrence. About 85 per cent of people with MS begin with this form, and more than half have this form of the disease at any one time.

Illnesses such as fibromyalgia, multiple sclerosis and epilepsy also vary over the menstrual cycle, with symptoms often worsening just before a woman's period starts. Most epileptic seizures, for instance, occur in the morning or in the evening.

Sleep disorders are quite common, but once diagnosed are often readily treatable. Those engaged in an irregular day-night pattern of work and rest, and have a medical sleep disorder face the worst challenges. However, shift work has a direct and immediate effect on sleep. This is because of ups and downs in circadian rhythms that boost alertness in the morning, making it difficult to obtain long blocks of daytime sleep and external factors such as noise, sunlight and family obligations, which often interrupt or cut short sleep.

Problems for Night-time Workers

When along with quantity, the sleep quality suffers, people spend less time in the deeper stages of sleep, which are critical for recovering from physical fatigue. They also may receive less Rapid Eye Movement (REM) sleep, considered important for mental health. Shortened and poor quality

sleep may be implicated in troubles of the nervous system, changes in behaviour patterns, persistent anxiety or depression. This can also act as an aggravating factor for other psychosomatic complaints or diseases, for instance gastrointestinal and cardiovascular.

Higher rates of gastrointestinal (GI) problems are documented among shift workers—digestive problems such as constipation, diarrhoea, excessive gas, abdominal pain and heartburn. Peptic ulcers are two to five times more prevalent in shift workers than day workers according to case studies. In addition, shift work may speed the onset of ulcers. In one study of Italian workers, the time between the start of work and diagnosis of an ulcer was 12 years for day workers, 5.6 years for permanent night workers and five years for workers on a rotating eight-hour schedule. Another study found that German shift workers had twice as many long-term absences (more than 28 days) due to GI diseases than day workers. A range of factors is believed to cause the elevated incidence of GI problems, with the main one being that people have difficulty digesting food during the overnight hours. Other contributing factors include disturbed sleep, poor eating habits, overeating, excessive coffee, smoking and psychological stress.

The general consensus among researchers is that lack of quality sleep raises the risk of developing coronary heart disease (CHD) or ischaemic heart disease (IHD). This may be true for people working during the night—doctors, nurses, shift workers, etc. One of the few studies to look at heart risk in women found that American nurses, who worked on rotating shifts for six years or more, had an elevated risk of 51 per cent for CHD. In one rotating shift workers with a Japanese computer manufacturer had significantly higher total cholesterol levels and slightly higher triglyceride levels than day workers. An earlier study of 910 Belgian men of age 25 to 40 found that those with the most irregular working hours had significantly higher total and low-density lipoprotein (LDL)—cholesterol and lower

high-density lipoprotein (HDL)—cholesterol. Since high levels of LDL-cholesterol in blood are a primary cause of heart attacks, it is termed as the 'bad' cholesterol and HDL-cholesterol which helps remove cholesterol from tissues is termed as the 'good' cholesterol. Therefore, the higher levels of LDL-cholesterol in these men indicate a higher rate of heart attacks.

People with lack of sleep also complain of mental health symptoms such as nervousness, chronic fatigue, anxiety, restlessness and irritability. For example, a study of workers at chemical factories in India found that for every question relating to mental health, such as "Do you feel like a nervous wreck?" and "Do you react with irritation even when you don't want to?"—the night workers scored higher than day workers. And a study at an oil refinery in Austria found a prevalence of 'psychoneurotic disturbances'—complaints such as restlessness, nervousness and anxiety—among shift workers.

Relatively little research has looked at the link between shift work and more serious mental health problems. Currently, there is no strong evidence that shift work by itself causes psychiatric problems, but some researchers believe that if a person is predisposed to a mental health problem, it can serve as a trigger that brings on a problem. A few small studies suggest that shift work may be linked to depression. A study of Italian textile workers found that night workers reported a far higher incidence of anxiety or depression requiring treatment with psychotropic drugs for more than three months, or hospitalisation.

Problems Caused in Night-time Women Workers

Research studies around the world have shown that there may be chances of delayed conceptions in women who do not sleep properly. Their risk of miscarriage too may increase, suggests a Canadian study. French researchers found that shift work amongst women may increase the risk of premature births by 60 per cent. Studies in Finland and

China found that women shift workers have an elevated risk of giving birth to low birth-weight babies. While these studies do show that lack of sleep may be linked to risks to women's reproductive health, more research is needed to conclusively document the risks.

Scientists looked specifically at breast cancer risk among female shift workers. Because this study guessed at night-work schedules based on statistical data at the women's workplaces, future research involving personal interviews with subjects may throw more light on the relationship between night work and breast cancer. Why night work might increase breast cancer risk is unknown. Researchers speculate that the risk may be related to night workers' altered sleep patterns and exposure to natural light, which can influence levels of the hormone: melatonin. Though primarily released in the late evening in anticipation of sleep, melatonin also influences body levels of estrogen, a hormone, excess quantities of which are thought to be associated with breast cancer. Yet, we need more research before we can say why it is that night work increases breast cancer risk. The American Cancer Society's website states that the best way for women to lower their risk of breast cancer is to reduce known risk factors, whenever possible. Factors that increase breast cancer risk include obesity, high-fat diets, consuming two or more alcoholic beverages per day, taking oral contraceptives or hormone replacement therapy, physical inactivity, and having one's first child after the age of 30.

Health Risks in Working by Night

Most health problems attributed to night-time working or shift work are believed to result from the fact that it requires people to invert the normal cycle of being awake and active during the day and sleeping at night. For most people, the body's circadian rhythms and daily fluctuations in body functions stay oriented to daytime living. Body temperature, for example, rises in the afternoon and dips during the overnight hours, while the production of the hormone,

melatonin, follows the opposite pattern. It is different for night-time workers. Working consecutive night shifts prompts circadian rhythms to slowly begin to shift, but factors such as the cycle of sunlight and darkness, the tendency to revert to daytime living on off days, and the need to rotate shifts prevent complete adaptation. Living and working 'out of sync' with circadian rhythms as well as constantly shifting them places stress on one's body, and this may potentially lead to health problems.

Symptoms of Diseases

The time of the day can affect the way our bodies respond to medical therapy, especially drug therapy. Disruptions in the body clock itself may undermine health, making you fall asleep too late, wake up too early, or suffer 'blue moods'. Chronotherapy offers new ways to reset your body clock and resolve such problems. The 24-hour body clock is important because many of our normal body functions follow daily patterns of speeding up and slowing down, intensifying and diminishing, in alignment with circadian rhythm. Interestingly, so do the symptoms of a number of chronic disorders.

People with allergies sneeze through allergy attacks every spring and summer while symptoms of allergic rhinitis, a nasal inflammation associated with hay fever, such as sneezing, runny nose, and stuffy nose become typically worse in the early waking hours than during the day. The symptoms in asthma patients are 100 times more likely to occur in the last few hours before awakening than during the day. Chest pain and electrocardiogram (ECG) abnormalities in stable angina patients are most common during the first four to six hours after awakening. In unstable angina, ECG abnormalities are most common during sleep while chest pain can occur even while at rest. Symptoms of rheumatoid arthritis turn more intense upon awakening while symptoms of osteoarthritis worsen in afternoon and evening. Pain during the ulcer disease typically occurs after

emptying of the stomach, following daytime meals and in the very early morning, disrupting sleep. Highest blood pressure readings occur from late morning to middle afternoon, while they show lower readings during early sleep. Epilepsy symptoms too often occur only at a particular timing of the day or night, yet individual patterns differ among patients.

Chronodiagnosis—'Test-time'

Symptoms occurring at specific timings can indicate the 'test-time'. Also, alterations in the body's most dominant rhythm, the daily wake-sleep cycle, provide an important clue to alert you that something is wrong and that it's time to get tested. Complaints about fatigue and poor sleep generally trigger visits to the doctor for diseases as diverse as AIDS, diabetes, depression, and multiple sclerosis. Time of day patterns can help identify causes of many illnesses. Bringing symptom patterns to your doctor's attention may help your doctor to figure out what is wrong, faster and more accurately. For instance, the predictable morning spurt in blood pressure and clotting of red blood cells make heart attacks and strokes peak in the morning, too. Disruptions in the flow of oxygen to the brain in sleep may produce morning headaches.

Medical chronobiologists have found that biological rhythms can affect the severity of disease symptoms, diagnostic test results and even the body's response to drug therapy. Now these investigators are working to discover how the rhythms of life can be used to improve the practice of medicine—and your health. Interestingly enough, they found that the human body clock affects diagnostic testing as well. The time of day you take diagnostic tests or undergo medical procedures alters the results. These results can vary significantly, possibly producing inaccurate readings, depending on the time of the day when a test is done. Medical chronobiologists are working to develop test-interpretation guidelines for doctors that take circadian rhythms into account.

We know that the body clock affects blood pressure. It is not constant throughout the day and night. It normally rises in the morning, remains elevated during the day and early evening, and decreases to its lowest level during sleep. So, a single reading taken during the day may not give a true picture of whether blood pressure is within the normal range or requires treatment. Some doctors now ask patients to wear special monitoring devices. These provide a complete 24-hour blood pressure pattern by recording blood pressure a number of times during the day.

The body clock may complicate testing for asthma severity. Your airway function will vary over the day. We know that the airway potency, or degree of openness, is poorest during the night and best during midday and evening. If you routinely go for a check-up in the afternoon, your doctor may think your treatment is working fine. But if you routinely go for a check-up first thing in the morning, the severity of your illness will be more apparent. The same is generally true for forced expiratory volume and peak expiratory flow readings, which can be up to 50 per cent higher at midday and afternoon than overnight or when the patient wakes up. Unless these circadian rhythms are taken into account, daytime evaluation of asthma patients could result in underestimating the severity of the disease. The body clock also affects skin testing for allergies. Results are lower in the morning, considerably higher in the evening, and greatest just before bedtime.

For women who still have their periods, the best time to get a mammogram is five to 10 days after a period because the breasts are less lumpy and less tender, and it becomes easier to get a good reading. For those women who no longer menstruate, the timing is not as important. One recent study of 2,500 women, conducted at the Fred Hutchinson Cancer Research Center in Seattle, found that women who wait until two weeks after they start their period have the best chance of getting a more accurate reading. Women who wait more than two weeks after their period starts are twice as likely

to miss an early diagnosis of cancer. When women wait longer than two weeks, there are increased levels of the hormones— estrogen and progesterone, which cause fluid retention in the breasts and trigger breast cell growth. Both of these can obscure readings; so avoid mammograms at those times. The real issue in post-menopausal women is not to forget to get your mammogram done.

Accurate diagnostic test results can help doctors treat the disease. Based on chronobiology, general practitioners can now predict many disorders. When called in the late evening, they can forecast that their patient might have a flare of a peptic ulcer. If summoned in the early morning, they may anticipate seeing a patient with an asthma attack or a woman about to give birth.

Chronotherapy

"The biology of human beings is not constant throughout the day, the menstrual cycle, and the year," says Michael Smolensky, Director of the Chronobiology Center at the University of Texas, "instead, it varies predictably in time." Co-ordinating biological rhythms (chronobiology) with chronotherapy will help consider a person's biological rhythms in determining the timing and, sometimes, the amount of medication to optimise a drug's desired effects and minimise the undesired ones. Patients are therefore, more likely to follow schedules for taking their medications when the latter are formulated as chronotherapies because of better medical results and fewer adverse side effects. With better compliance, the disease can be better contained, which means fewer doctor visits and potential trips to the hospital because of acute flare-ups.

"Do you take your medicines on time?" asks the doctor. You might be wondering that besides making sure I'm not late for my doctor's appointment, what does time have to do with medicine? Maybe more than you think. If you get sick, chances are you will take your medication at specified daily times. Think how often a doctor has handed you a

prescription, saying, "Take this medicine three times a day." By linking 'medicine-taking' to mealtimes, the doctor knows you will be more likely to remember to take your medicine. A 'four-times-a-day' prescription also adds bedtime to the list. This approach is now branded as obsolete.

The latest approach is drug chronotherapy, which for the most part does not involve new medicines but using old ones differently. Revising the dosing schedule, reformulating a drug so its release into the bloodstream is delayed, or using programmable pumps that deliver medicine at precise intervals are some of the simple changes that may reap enormous benefits. The Food and Drug Administration (FDA) regulates drugs that are reformulated as chronotherapeutics.

Prescribing equal doses over the day means that your need for medication is the same all day, and that a consistent amount of medication confers a uniform benefit at all times. You know that your symptoms wax and wane over the day, and therefore, you need proportionately more medication to control them at some times, and less at others. Moreover, the way your body absorbs, uses, and excretes drugs varies over the day. The same dose of medicine may be too much at one time, and too little at another. Medicine that may help you at one time may not work as well at another; it may not even work at all. At some times, it may even be harmful.

Take for example aspirin, one of the world's most widely used medications. Aspirin is safe as far as it is taken in relatively small doses now and then. The problems arise mainly with prolonged use, since aspirin may irritate the lining of the stomach and cause stomach ulcers and bleeding. Taking aspirin at a proper time dramatically lowers your risk of developing stomach irritation and injury. Aspirin is least likely to cause irritation if you take it at night, and most likely to do so if you take it in the morning. Some persons who cannot tolerate aspirin when they take it in the morning have little or no difficulty when they take it at night.

It is a generally an accepted rule that homeostasis—the concept that body functions are in a constant 'steady state' throughout the day and night, and that the goal of treatment is restoring or maintaining this 'steady state'. Even the treatment itself may have this goal: for example, a prescribed drug is given in a way: every four hours that theoretically will ensure a steady level of it in the patient's bloodstream. Obviously, this view contrasts sharply with diagnosing and treating illness chronobiologically – 'by the clock'.

Practising Chronotherapeutics

Although chronobiology is not yet taught in medical schools, doctors are increasingly taking biological rhythms into account in diagnosing and treating illnesses. They are recognising that whereas homeostatic mechanisms keep the body functioning continuously on a moment-to-moment basis (for example, by maintaining breathing and heart beat), biologic rhythms programme the body 'in advance' for coping with its predictably changing needs, such as varying energy requirements during specific time cycles. It is time, say the medical experts, when chronobiology, and particularly the body clock, will play a vital role in many areas of medical practice.

Research on trying to figure out which time of day chemotherapy would kill tumour cells better, and yet cause fewer side effects, like nausea and vomiting, is in progress. How does one figure out the clock within one's own body and that of family members? Interestingly, it varies, depending on where you live, how old you are and what your gender is. Consider a baby's clock that requires 20 to 22 hours of sleep a day, versus that of a peri-menopausal woman, who may have difficulty in sleeping and may only get six hours a day. In addition, if you live in Alaska, you will find that your internal clock is set by the number of hours of daylight. We have to be careful when we talk about a person's 'internal clock' that we differentiate as wake-and-

sleep cycles from other cycles that may be particular to certain organs. We do know that some breast tumours are more receptive to surgery and chemotherapy during various phases of the menstrual cycle. The timing will depend on the type of tumour, the size of tumour, and the particular medications the doctor has in mind.

Among the various biological rhythm cycles that medical chronobiologists study, the 24-hour day-night and activity-rest cycle is considered a key 'chronobiologic' factor in medical diagnosis and treatment. In this rapidly growing medical field of chronobiology, researchers are learning how to treat a disease with these biological rhythms using 'chronotherapeutics': matching drug therapy to the body clock. Medication or surgery in tune with the body clock can now cure diseases faster and better. Researchers are beginning to use chronobiology to figure out how diseases might be treated with these biological rhythms in mind. What is new is applying chronotherapy to various maladies and tailoring medicines so that they will work in an optimal fashion.

Research has shown that there is indeed a best time to take pills, an ideal hour to hit the treadmill, and a certain time of month that allows women to get the most accurate mammogram results. Your medication might be more effective if you took it at a different time of the day. Most of our bodily functions, including digestion, respiration, and hormone production, fluctuate over the course of a day, month and even year because of the ways our bodies respond to light, darkness, temperature, activity and sleep. Most diseases will have specific timings for taking medicines, depending upon the time at which the disease flares up or its symptoms worsen. Taking treatment at these specific times will hasten the curing process and help take care of the aggravated symptoms.

Chronotherapeutic Approach to Diseases

Asthma: Chronotherapeutic approaches are already being

used to treat asthma. Chronotherapy for asthma is aimed at getting maximal effect from bronchodilator medications during the early morning hours. For instance, a new formation of theophylline, the standard medicine for asthma, which normally delivers the drug uniformly throughout the day, delivers more of the drug at night when it is needed the most. The best results show that if the medicine is taken between 5 and 7 p.m, the non-steroidal medicines take a few hours to work. So they perhaps work around 11 p.m., when the lungs need them most.

Persons with severe unstable asthma live on a conventional awake-in-the-daytime, asleep-at-night schedule. For these people therefore, late afternoon may be the best time for medication because for those who wake up several times a night gasping for breath, a good night's sleep can be a dream come true. All of us have a decrease in lung function during the night, but for asthmatics, the drop may be as much as 50 per cent. So the good news is that if you take oral or inhaled steroids between 3 and 5 p.m. in the afternoon, you may have less of a drop in lung function and your lungs will be healthier. If you are a night worker, your may need to synchronise treatment time with your schedule.

Arthritis: Rhythmic patterns have been observed with arthritis pain. People with osteoarthritis, the most common form of the disease found in elderly and aged individuals, tend to have less pain in the morning and more at night. But for people with rheumatoid arthritis, the pain usually peaks in the morning and decreases as the day wears on. Chronotherapy for all forms of arthritis consists of non-steroidal, anti-inflammatory drugs and corticosteroids; however, the dosages are timed to ensure that the highest blood levels of the drug coincide with peak pain. For people suffering from osteoarthritis, the optimal time for a non-steroidal, anti-inflammatory drug, such as Ibuprofen would be around noon or mid-afternoon. The same drug would be

more effective for people with rheumatoid arthritis when taken after the evening meal. The exact dose would depend on the severity of the patient's pain and his or her individual physiology. Anti-inflammatory medicines can thus be timed for maximum effect.

Ulcer: Ulcer patients are advised to take their medicines in the evening because the acid secretion in the stomach reaches a peak at that time and the drugs can neutralise that acid.

Thyroid problems : The first step is to separate a true thyroid problem from normal metabolic fluctuations. We know that the metabolic rate is higher in the afternoon, but if you find yourself with lack of energy, difficulty controlling your body temperature, and you are worried that something more may be going on, ask your doctor to get a simple thyroid test.

Problems in Women

For peri-menopausal or menopausal women, hormone replacement therapy depends on what kind of hormone is required and the method of getting it. For instance, many women taking estrogens and progesterone will take it in the evening. Other women use a patch, and the timing is not so critical. However, this is probably one area where the precise timing of the medicine is not as crucial.

Surprisingly, a woman's reproductive system, can, oddly enough, cause changes in her teeth. Changes that take place in a woman's body during puberty, menstruation, pregnancy, lactation and menopause can impact their dental health, according to reports from the Academy of General Dentistry. Younger women may notice swollen inflamed gums, cold sores and canker sores when they are menstruating. Pregnant women, in particular, can see changes in their mouth during their pregnancy. Hormonal changes in pregnant women causes increased oral sensitivity, which often means swelling and inflammation of the gums, or gingivitis. Pregnant women should therefore keep a strict

regimen of brushing and flossing, and see the dentist more frequently to treat or prevent gingivitis. Women going through menopause may experience gum pain, burning tongue, bad taste and dry mouth, as well as bone loss due to osteoporosis.

Migraine: Some people get migraines while others don't. For women, hormonal fluctuations can be a trigger for migraine attacks. Depending on the regularity of your attacks, consider taking your medication at night to prevent a headache. And if you know that certain foods like chocolates, nuts and wine are a trigger, avoid those foods in the evening.

Ruling out stress and anxiety: Many doctors suggest taking antidepressants in the evening. This is because many symptoms will be minimised while you sleep. Some antidepressants have a natural sedative effect, and you can minimise drowsiness by taking them at night instead of during the day. However, as with any serious medication, make sure your doctor is on board with your plans, because if you are taking other medications too, there could be interactions that you might not be aware of.

Allergy: Antihistamines generally have a sedative effect and it is therefore best to take them in the evening. On the other hand, decongestants, which have a stimulating effect, should be avoided at night and taken during the day.

Blood pressure and heart problems: Blood pressure and the risk of heart attack and stroke are highest in the early morning hours. So it makes sense that if you are on a long-acting blood pressure medicine, you might want to take your medication at night, so it works for you in the morning. But there are individual differences, so it is better to check blood pressure for a couple of days and get to know the ups and downs, and then go over the readings with your doctor and

plan your medication schedule. Chronotherapeutic antihypertensive drugs are now available, especially the calcium-channel blockers that deliver unequal amounts of medication throughout the day, following the circadian rhythms of blood pressure. It has been shown that ischaemia and heart attacks are much more common in the morning than at other times of the day. Drug treatment for heart disease should be targeted in accordance with this marked circadian rhythm.

Cancer: Research studies so far suggest that there may be different chronobiological cycles for normal cells and tumour cells. If this is true, the goal would be to time the administration of cancer drugs to the chronobiological cycles of tumour cells, making them more effective against cancer and less toxic to normal tissues. The trouble would be how to handle the logistics of giving drugs at scattered times throughout the day and night. Chronotherapy for cancer means bringing in cancer patients to the hospital in the morning to receive their drug therapies, or in the late afternoon or even in the night. Portable infusion pumps may hold the answer. The patient can be sent home with an implantable pump that will automatically distribute the drug at the appropriate time.

A 60-year old woman with colon cancer was forced to terminate a chemotherapy course recently because of its severe side effects. But today she gets twice as much of the drug she could not tolerate, with no adverse reactions. This is because her treatment was co-ordinated with her body's natural biorhythm. The woman was given heavy doses of chemotherapy through a programmable pump while she slept. During the night, the non-cancerous cells of her digestive tract were at rest and therefore, less susceptible to the toxic effects of the potent medication. Her cancer did not regress but most importantly, it did not progress. In cancer, cells are most vulnerable to damage when they are dividing.

According to the American Medical Association, anti-cancer medications attack different stages of the cell reproduction rhythm. Some, such as 5-fluorouracil, which is used to treat cancers of the intestinal tract, are best tolerated and cause the fewest side effects when given by infusion while the patient sleeps at night. Others, including Adriamycin and Doxorubicin, which are used to treat bladder, ovarian, and other cancers, are best tolerated when given in the morning. When cancer medications are given in a chronobiological manner, that is, according to body rhythms, patients may be able to tolerate higher, more potent doses than would be possible otherwise.

Doctors advise not to wait for the surgery if doing so puts you at risk of having the cancer spread faster. Yet, timing surgery to monthly hormonal cycles, especially for breast cancer, may make a life-or-death difference. Studies have also shown that it is best to have breast cancer surgery done during the third week of menstrual cycle. This is because researchers have found that women whose mastectomies or lumpectomies are performed in the week after ovulation are up to four times as likely to survive, disease-free, for at least 10 years.

One hypothesis that explains this is that progesterone levels are at their highest, which seem to boost the immune system and block cancer cells from spreading. Many experts believe that any improved outcome is indeed hormone-related. In the first half of the menstrual cycle, estrogen levels are high, and progesterone is not produced. In the second half, progesterone rises and estrogen falls. It is believed that progesterone may inhibit the production of some enzymes that help cancer spread. However, some experts dispute the need to time breast cancer surgery according to the menstrual cycle. G.M. Clark, of the University of Texas Health Science Center at San Antonio, reported at the May 1996 International Conference on Breast Diseases in Houston, USA that retrospective analyses from at least 23 studies, involving more than 6,000 patients, failed to find any

significant impact of the menstrual cycle division on breast cancer prognosis.

Therapeutic Applications of Light

Light has been valued throughout history as a source of healing. Today the therapeutic applications of light are being investigated in major hospitals and research centres worldwide. Results indicate that full-spectrum white light can have therapeutic value for a range of conditions, from chronic pain and depression to immune disorders. Many health disorders can be traced to problems with the circadian rhythm. Disturbances in this rhythm can lead to health problems. Natural sunlight and various forms of light therapy can help re-establish the body's natural rhythm and are becoming an integral part of the treatment for many related health conditions.

Understanding circadian rhythms may be relevant to the understanding and treatment of diseases. Therapy can be more effective and toxic effects reduced when drugs are administered at carefully selected times of the day. Evidence suggests that taking medication 'by the clock' helps the drugs work better and reduces their side effects. Drugs that may be given as per the body clock include corticosteroids, non-steroidal anti-inflammatory drugs, antihistamines, theophylline, and anti-cancer drugs. The list is growing as the medical community slowly accepts chronobiology, chronotherapeutics, and the diagnostic and treatment methods derived from them. Although chronobiology is not new to medical science, it is still in the process of being accepted by the medical community. Keeping records of the time you take medicines, the severity and timing of symptoms, etc. will help you and your doctor to plan for your treatment schedule and adjust your therapy to align with your body clock. For now is your time to get more into the rhythm of life!

According to the American Medical Association, events occurring at certain times are as follows:

Asthma attacks	between midnight and 6 a.m.
Heart attacks	between 6 a.m. and noon.
Angina	between 6 a.m. and noon.
Rapid rise in blood pressure	between 6 a.m. and noon.
Highest blood pressure	between noon and 6 p.m.
Nasal allergy symptoms	between 6 a.m. and noon.
Migraine headache	between 6 a.m. and noon.
Rheumatoid arthritis—worst symptoms	between 6 a.m. and noon.
Onset of menstruation	between 6 a.m. and noon.
Onset of labour and childbirth	between midnight and 6 a.m.

Tips on medical timing for women, as offered by ABCNEWS medical correspondent, Dr Nancy Snyderman:

- The best time to schedule a dental appointment is after menstruation.
- The ideal time to give a self-breast examination is five days after menstruation.
- To relieve the symptoms of irritable bowel syndrome, the best time to take fibre is during the second half of your menstrual cycle.
- For migraine medication, the best time to take it is a few days before and a few days after menstruation.
- The best time to take asthma medication is in the late afternoon.

7

LISTEN TO YOUR BODY CLOCK AND MAKE AMENDS

Time conquers all, and we must obey.
I waste time and now doth time wastes me.

—William Shakespeare, playwright

Listening to your body clock, applying chronotherapy and chronomedicine in your day-to-day life is a major leap in scientific understanding: a new way to maintain and optimise health, and to prevent and treat illness, holds implications for vastly improving our lives. In many situations it would be advantageous for us to be able to manipulate the biological rhythms and the clocks that generate them. We encounter frequent disturbances in circadian rhythms as a

Fig. 7.1: Rest is essential.

result of rapid phase shifts, the displacement of a biological rhythm along its time axis as in shift work or jet lag, which causes dissociation between exogenous and endogenous components. So, it all depends on how you organise your daily life, with respect to sleep, rest (Fig. 7.1), meals, exercise, and other factors, which may make symptoms better or worse, and hasten or slow your recovery.

Coping Better at the Workplace

The biggest problems that shift workers face on their days off is that they revert back to the awake-in-the-daytime, asleep-at-night schedule that is traditional in our society. Ideally, a person who works shifts would try to stay on the same schedule seven days a week. Of course, if you work at night, it means that on your days off you would still be sleeping in the daytime, which probably would interfere with your family and social life.

There is a need to raise awareness of body clock issues in the workplace. There are many things that round-the-clock workplaces could do to help workers cope better with shift work. It would be to their advantage to do so, because better schedules promote higher employee morale, higher productivity, and lower job turnover. Among the things that companies could do is to adopt schedules that rotate forward around the clock, which is easier on the body. Companies could educate workers about body clocks, especially about sleep, diet and exercise. Allowing napping during breaks at the job may help prevent napping on the job.

One tactic that may help is to try to get quality sleep in the same time slot every day, regardless of the shift that you are on or how busy you are. This might mean disconnecting the telephone, shutting off the doorbell, and adopting other tactics to keep people from bothering you. But sleep is really important, and getting enough of it is probably the only way to avoid feeling exhausted.

Employees working at night can do the most boring tasks earlier and the most interesting ones toward the end

of the shift. They need to plan what and when they eat. Many people who work at night snack a lot, and as a result they often gain weight. Minimise the use of coffee when working at night. Also try and protect daytime sleep by making your room as dark and quiet as possible. This will possibly ease adaptation to working through the night.

Sleep Needs

Everyone has different sleep needs. There is no one-size-fits-all formula. An average adult probably needs about eight hours of sleep, but most of us get less than that. If you are getting eight or nine hours of sleep a night and you feel fully rested and alert in the daytime, that's great. You are listening to your body clock and doing what's best for you. Your sleep time must begin from the time at which you turn out the light, turn off the TV, turn off the computer and plan to go to sleep. It does not refer to the time you get into bed to read or watch the late-night news. Be careful not to become addicted to clock-watching during the night. The more concerned you are about what time it is and how little you have slept, the more anxious you will become, making it even more difficult for you to fall asleep. Another important criterion for you to consider is your sleep quality. How do you think you slept? Did you stay awake for a long period of time, anxious and distressed? Did you toss and turn? Wake up constantly? Were you exhausted in the morning? Did you feel groggy and unsatisfied at wake-up time? You may find it helpful to rate your sleep quality on a scale of one to six, with one signifying terrible and six being excellent.

Most people do not pay enough attention to how much sleep they need to feel fully rested all day long. Dr Deepak Chopra, the eminent writer, says man in general should always go to bed at 10 p.m. and wake everyday before 6 a.m. like the animals do. Most of us walk around sleep-deprived. Our internal clocks, if there were no television sets, no telephones, no outside disturbances, would allow

us to fall into that schedule more easily. Therefore, it is a common-sense approach that you should try for. Growing science suggests that power naps can refresh you in the afternoon. But naps are not a substitute for a good night's rest. If you are having an energy plunge, look first at your normal sleep patterns and diet. Many people who have afternoon energy binges are eating big lunches instead of grazing.

C.W.Hufeland, a German doctor in 1798 in *Die Kunst, das menschliche, Leben zu Verlangern* has rightly cautioned us, "Many people lamely believe that it matters not at all when they sleep these seven hours, whether in the daytime or at night. They indulge in their studies or pleasures as late into the night as possible and believe that it is all the same if they sleep on into the morning, the same number of hours that they have robbed from midnight. But I must ask everyone who values his good health to beware of this seductive error."

Dietary Changes

Diets can influence the sleep-wake cycle. What you eat, how much you eat, and even when you eat, all contribute to the quality of your sleep. What you eat can be a determining factor in how well you sleep. Heavy late night meals can deter sleep and cause heartburn. Obesity aggravates snoring and sleep apnoea. Studies suggest that foods containing tryptophan aid in sleep. Tryptophan is a naturally occurring amino acid (the building blocks of protein), which the brain converts to serotonin—a sleep-inducing hormone. Carbohydrate-rich foods such as rice, potato, pasta, bread, crackers, etc. boost serotonin, a chemical substance in the neurotransmitter in the brain, that induces drowsiness. Green leafy vegetables too contain serotonin, dopamine and norepinephrines, which help get sleep. On the other hand, a high protein-rich diet triggers an increase in the neurotransmitter, norepinephrine, which increases alertness. Avoid heavy or spicy foods just prior to bed. These meals can interfere with

sleep by causing heartburn. If hunger associated with an empty stomach keeps you from sleeping, try having a light snack, such as crackers, warm milk, or yoghurt before going to bed.

Do not use alcohol to help you fall asleep. Although alcohol may initially induce sleep, once it wears off, the sleep tends to be fragmented. Limit smoking prior to bedtime, as nicotine is a stimulant. Limit caffeine during four to six hours before bedtime. Approximately 50 per cent of the caffeine consumed at 7 p.m. remains in the body till 11 p.m. Remember that caffeine is present in many different foods, beverages and medications, for instance chocolates, coffee, tea, soft drinks (cola), etc. Limit liquids of any kind for at least 90 minutes before bedtime if the need to urinate wakes you up in the middle of the night. It takes about 90 minutes for the body to process liquids. This problem is especially common in older men.

Valerian is an herb that is believed to have a calming, relaxing effect on the body. It has been used for centuries and is believed by many people to be useful for insomnia, mild anxiety and restlessness. The exact mechanism of action is unknown. However, it may act as a depressant for the central nervous system, to produce a mild tranquillising effect and sleepiness.

Right Time for Exercise

Exercise can be done at any time, say experts. But according to biorhythm studies, our body is designed to exercise most easily during late afternoons. This is because the muscles in the body are most flexible and the joints move most easily at the time. If you look at the statistics, most sporting achievements have been accomplished in the late afternoon or in the evening. Peak performance in most sports occurs in late afternoon and early evening, when body temperature reaches its daily high. Respect for this body rhythm may decrease your likelihood of injuries, whether you're a neighbourhood jogger or an elite athlete. Training and

competition times may influence who wins Olympic Games and other high-powered sporting events. Stanford University scientists found that players' biological rhythms predicted winners of Monday-night football games better than the Las Vegas point spread did.

Regular exercise (Fig. 7.2) can increase your chances of getting a good night's sleep. People often worry about whether exercise in the evening will disturb their sleep. Even some sleep experts advise people not to exercise within three hours of bedtime. However, says Lynne Lamberg, co-author of *The Body Clock Guide*, "If people are comfortable exercising right before going to bed, there's no reason to avoid it. Some people say it helps them relax and fall asleep easily. If that's true for you, then late night is also a good time to exercise. Most importantly, a regular exercise, regular sleep-time and regular meals help to keep the body rhythms in line. Regularity helps body to prepare itself by secreting proper hormones, blood pressure or heart rate, making it easy to carry out that specific activity." However, the general consensus says that avoid exercise within three hours prior to going to bed as this will boost alertness and have a negative effect on sleep.

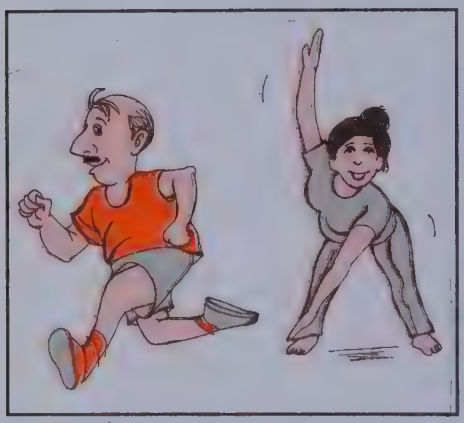

Fig. 7.2: Exercise at the right time.

Exercise specialists also say that it is best to pump iron in the morning, because by the end of the day, the neck and lower back muscles are fatigued from simply holding your head and torso erect. Lifting weights late in the day can lead to injury. But jogging may prove good in the late afternoon. Aerobic workouts are best done between 4 p.m. and 7 p.m.,

when your heart and lungs are strongest, and your metabolic rate is highest. Fit in the workouts before dinner, because once you have eaten, your heart works hard to pump blood to the organs involved in digestion. If your schedule does not fit in with this one, exercising in off-hours is better than not exercising at all.

Exercise is a good way to burn more calories. The best time to exercise is whenever it is convenient. A regular exercise schedule, like regular times for sleep and regular mealtimes, helps keep body rhythms in line. All of these activities help programme the body to expect the same activities at the same time the next day, and to prepare for them by secreting the proper hormones, raising blood pressure or heart rate or whatever is necessary and making it easy to do the specific activity. Whether the exercise is moderate or intense does not make a difference.

Treating Illnesses

Today, understanding the timing of body rhythms is changing the course of medical care. It is true that 'time and tide wait for no man', but now medical scientists say they are catching up with time. And what they are learning can improve both our health and our recovery from illness. Therefore, pay attention to the times that symptoms of illnesses occur, and talk to your doctor about whether the times you take medicine might improve your symptoms. It is true that 'chronomedicine' is a brand-new concept, not only for the average person but also for most doctors.

Chronotherapy, or timed treatment, aims to correct the underlying causes of a disease or reduce their adverse impact. Knowing symptoms' time of origin may enable your doctor to use more precise and effective treatment. Taking the right medicine at the right time for your body and your illness may boost the medicine's efficacy and cut its unwanted side effects. The upshot is that you probably will feel better, be more willing to continue taking the medicine, need to see the doctor less often for symptom flare-ups or

adverse drug reactions, and need fewer hospitalisations for chronic illnesses.

In the majority of the population, persons who stay awake in the daytime and sleep at night and who follow fairly regular schedules, the ups and downs of most daily rhythms prove quite predictable from day to day. Laboratories should report findings with a time-of-day correction factor. New ambulatory monitoring devices can show your doctor how your blood pressure, heart rate, activity/rest cycle, and other indicators of your health change around the clock. Computer programmes can analyse the data, making its collection and assessment practical.

Taking the right medicine at the right time for your body and your illness may boost the medicine's efficacy and remove its unwanted side effects. The outcome is that you probably will feel better, be more willing to continue taking the medicine, need to see the doctor less often for symptom flare-ups or adverse drug reactions, and need fewer hospitalisations for chronic illnesses.

Non-drug treatments may help correct underlying disturbances in the body clock. Exposure to sunlight-equivalent light, as one example, is now held to be the treatment of choice for persons with winter depression. Light exposure also benefits elderly persons who sleep poorly and wander at night, as well as shift workers and jet-lagged travellers. If you have insomnia but stick to a regular wake-up time seven days a week, however bad the night, for instance, you will probably sleep better in the long run than if you succumb to the impulse to sleep in.

It used to be that when dawn arrived, the men would go off to the hunt while the women tended to the children. When the men arrived that evening with the food, the women prepared it, all ate, and then all fell asleep, exhausted. It was work all day and sleep all night. Even with the advent of farming, the work and daily activities were by the light of the Sun, and at night everyone slept.

Today there are over a hundred cable channels, bars

opening till late, late night movies, late dinners, discos, dancing, partying, hanging out until wee hours of the morning—all of the modern entertainment obligations if we want to lead a 'full' life. Unfortunately, we, one-life humans, try to lead a two-life existence on one circadian rhythm. Our hormones, meanwhile, still adjusted to hunting wild boars by day and sleeping by night, carry on as best as they can. The hormones of yesteryears think the lifestyle of today is crazy. But being human does have its advantages. We do in fact have a great big brain that allows something the other animals do not have—flexibility. When life becomes more complicated, we adjust because we can. The bedlam of hormonal mismatches is not all that mismatched after all. We do get along fairly well, even trying to cram two lives into one.

We may prefer our air-conditioned homes with city services over cave-living, but the further we get away from our true circadian and natural lives, the more our internal systems have to adjust to the new world orders. We can reset the thermostat with some flexibility, but there are limits beyond which the system will not work.

Glossary

Biological clock	An internal time-keeping mechanism, capable of driving or co-ordinating a circadian rhythm.
Biological rhythm	Self-sustained cyclic change in a physiological process or behavioural function of an organism that repeats at regular intervals.
Circadian	Taken from Latin words, meaning 'around' and 'day'.
Circadian rhythm	A self-sustained biological rhythm which, in an organism's natural environment, normally has a period of approximately 24 hours.
Circa-annual	A biological rhythm with a period of about one year.
Cyanobacteria	A type of bacteria within genus *Synechococcus*.
Diurnal	Performed in or belonging to daytime; opposite of 'nocturnal'.
Endogenous	Self-sustained rhythm generated within an organism.
Entraining agent	An environmental time cue, such as light, that has the ability to reset a biological clock.
Exogenous	Rhythm generated within or by an organism because of rhythmic environmental cues that are external to the organism.
Free running	Natural self-sustained rhythm that exists in the absence of all environmental cues. When a human is free running, his/her cycle appears to be slightly longer than 24 hours.

Heliotrope	One of the several species of plants whose flowers or stem buds face east in the morning, follow the movement of the Sun during the day, and face west in the evening.
Homeotherm	Organism, whose internal body temperature is maintained at a relatively constant temperature through the organism's metabolic activities; its body temperature typically does not change in response to changes in environmental temperature fluctuations; homeotherms were once called 'warm-blooded'.
Hypothalamus	Small area of the brain near the top of the brain stem; controls site of behaviours, such as feeding or drinking, temperature regulation, secretion of hormones through its effect on the pituitary gland.
Infradian	Describes processes having periods much greater than 24 hours.
Melatonin	A hormone secreted by the pineal gland; used as a marker of circadian rhythmicity in humans.
Phase shift	The displacement of a biological rhythm along its time axis.
Period	The time that elapses before a rhythm starts to repeat itself.
Pineal gland	A cone-shaped gland situated in the brain. It secretes the hormone, melatonin.
Pituitary gland	An endocrine gland situated in the brain. It secretes several hormones.
Photoperiodism	The length of light in a light-dark cycle.
Poikilotherm	Organism, whose internal body temperature varies with and remains close to environmental temperature; poikilotherms were once called 'cold-blooded'.
Pulsatile	Rhythmic regular movement.

Sleep debt	A deficit in normal sleep time.
Tau	This term refers to an organism's period length.
Ultradian	Describes processes having periods much less than 24 hours.
Zeitgeber	Taken from German words meaning 'time givers'; an environmental time cue such as sunlight, food, noise, or social interaction that usually helps reset the biological clock to a 24-hour day.

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Almost every form of life—plant, animal or human being has an internal clock for measuring time, giving rise to rhythms. Rhythms are controlled by a 'biological clock' situated in the brain. This clock strongly relies on sunlight and darkness. In humans, too, there are internal clocks that regulate metabolism, physiology and behaviour. When we are well, our body rhythms work in synchrony but illness, travel across multiple time zones, shift-work schedules, etc. often throw the rhythms out of tune. This book makes us feel the presence of the 'body clock' within us and realise its importance in bodily functions. Listening to our body clock tick and making amends in our day-to-day life holds implications for improving our lives.

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